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Contents

FRONTISPIECE	SIR GEORGE NELSON
PAGE 1	A NEW YEAR MESSAGE TO THE INSTITUTION
2	CORROSION AND CATHODIC PROTECTION IN KUWAIT *by* J. S. GERRARD, GRADUATE
7	CHEMICAL GENERATION AND STORAGE OF ELECTRICITY *by* A. M. ADAMS, M.A., A.INST.P.
14	NEW INDUSTRIAL INSULATING MATERIALS *by* W. P. BAKER, B.SC.(ENG.), ASSOCIATE MEMBER, and F. S. EDWARDS, M.SC., MEMBER
16	HOME EVENTS
21	NEWS FROM ABROAD
22	CONVENTION ON DIGITAL COMPUTER TECHNIQUES
23	THE LONG-TERM INDUSTRIAL OUTLOOK FOR BRITAIN *by* G. L. E. METZ, M.I.MECH.E., MEMBER
26	A DISCUSSION MEETING: TRANSFORMER LIMITS
28	A REVIEW OF THE *PROCEEDINGS*
47	OBITUARY
49	CORRESPONDENCE
50	MONOGRAPHS AND PAPERS PUBLISHED SEPARATELY THIS MONTH
52	TECHNICAL PUBLICATIONS
54	SOME RECENT BOOKS
55	LIBRARY ACCESSIONS
56	ANNOUNCEMENTS TO MEMBERS
60	OFFICERS OF THE INSTITUTION
61	COMMITTEES, 1955–56
64	LOCAL CENTRE COMMITTEES, 1955–56
68	OVERSEA REPRESENTATIVES OF THE COUNCIL
68	OVERSEA BRANCHES, COMMITTEES, AND JOINT GROUPS
70	REPRESENTATIVES OF THE INSTITUTION ON OTHER BODIES
76	CODES OF PRACTICE COUNCIL
78	FORTHCOMING EVENTS AT SAVOY PLACE
79	BRITISH NUCLEAR ENERGY CONFERENCE
79	ELECTIONS AND TRANSFERS
82	CONTENTS OF THE CURRENT ISSUES OF THE *PROCEEDINGS*
82	DISTRICT MEETINGS

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George E. Nelson

PRESIDENT 1955–1956

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A NEW YEAR MESSAGE TO THE INSTITUTION

THE YEAR JUST ENDED WILL BE MEMORABLE for the British people. During 1955 the country reached an unprecedented level of internal prosperity, there was considerable relaxation in East-West tension and we enjoyed the finest summer and autumn for many years.

The Institution has played its full part in various fields, on its own and with kindred professional Institutions, in promoting the interests of the country and our profession, and has had one of the best attended and most successful summer visits, to hydro-electric engineering monuments amongst the beauties of Scotland, which was not marred even by the railway strike.

Such conditions have engendered feelings of optimism and if this acts as a tonic to encourage everybody to face, and fully to play their part in solving, the problems associated with the needs of the country in 1956 and beyond, that optimism may well be justified, but it will be so only on these premises of more efficient and greater effort. In the circumstances, we must guard against complacency and against permitting our improved fortunes to be an excuse to relax our efforts. All possible steps must be taken to improve the basis of our national economy and to increase our facilities for scientific and technical education to meet the needs of our long-term requirements.

The strain of recent years has been very great and it is natural that with these first signs of improvement comes an inclination to relax, as shown by the fall in our fuel stocks, which will be inadequate to meet our needs should the glorious 1955 summer be followed by a severe winter. This is due not to a lack of coal itself in this country but to a failure to extract a sufficient quantity to meet our fast and continually growing needs. This underproduction of a basic material, together with the inflation of our economy, serves to remind us of the difficulties ahead. The great increase in spending during the last twelve months has aggravated inflation and compelled the Chancellor to introduce an autumn budget in an endeavour to arrest its continuance.

Another manifestation of this inclination to relax is the disagreement amongst the Western allies after the meeting at Geneva. These symptoms unfortunately remind us that so often in the past great things have been mainly achieved under the compulsion of outside circumstances, indicating that the world has still not moved towards that degree of self-discipline which results in people doing their best for its own sake, without external pressure.

This still is perhaps the greatest challenge to our way of life. How can progress be achieved without crises and external difficulties, and how can relaxation and perhaps degeneration be avoided after the solution of major problems? History tells us of empires and civilizations which, when they had overcome external dangers and difficulties, collapsed from internal decay, and of nations which, having defeated their enemies, turned on their allies so that all perished through mutual destruction.

Let us hope that the present signs of relaxation are not the first steps along that unfortunate path, but rather that they are only pauses for breath, in the continuous struggle to find solutions to the manifold political and economic problems of the world.

In the international sphere, although at Geneva the leaders of East and West decided to conduct their disagreements in a civilized fashion, no major issues have in fact been resolved, and actual disagreements still persist practically undiminished. Consequently, although the danger of war is no longer imminent, the position is controlled mainly because each side respects the military strength of the other. This imposes on us the necessity of continued expenditure on the production of armaments, and on the search for better armaments in the future.

The solution of these problems, present and future, demands the unremitting efforts of electrical engineers on research, development, design and manufacture of electrical machinery for both home and export, and the provision of cheap and plentiful power to make all our export industries competitive in the world market. In

introducing further economies, including the techniques of push-button control, we should give full consideration to bringing about rationalized production, and in these ways ensure that the most efficient use is made of our most precious national resources, namely scientific and technical personnel in Government and industrial services.

In my Inaugural Address I drew attention to the problem of securing men with suitable qualifications at all levels, to undertake these multifarious tasks. For years past, successive Presidents have referred in their New Year messages to this overriding problem, and each while in office has devoted much of his efforts towards a solution. The efforts of the entire profession in the past have not enabled us to do more than hold our ground, and now, unfortunately, there are signs that we might lose ground. This must be avoided at all costs.

The apparent prosperity of 1955 cannot become real until it is oriented with a world-wide expansion of trade to which our own must be properly related and integrated if stability is to be achieved. The consequent demands accentuate the need for more scientists and engineers, and therefore in the coming year we must increase our efforts and facilities for the recruitment and training of more men in these fields, and, most important of all, take steps to ensure, as I have already mentioned, that full and efficient use is made of this most precious asset.

In the wider picture, I would say that we can enter 1956 and the future with optimism only if we are all resolved to ensure that our efforts towards improving the basic economy of our country and our Commonwealth are the greatest possible. Having confidence in my fellow countrymen at all levels, I am sure that given proper leadership they will play their part in the solution of these problems, so that our children and their children will bless us for our efforts and our achievements to bring them stability and happiness.

To each one of you I extend my sincerest and heartiest good wishes for happiness and prosperity in the coming year.

George A. Nelson

PRESIDENT

Corrosion and Cathodic Protection in Kuwait

J. S. GERRARD, Graduate

A great financial loss is incurred by the nation every year through the corrosion of metal structures. Although cathodic protection was proposed by Sir Humphry Davy in 1824 it is only in the last few years that serious efforts have been made to apply the method. The author, who is with Metal and Pipeline Endurance Ltd., worked for some time in Kuwait for the Kuwait Oil Co. and describes here the measures taken to protect the oil installations there. The article is based on a paper entitled "Corrosion and Preventive Measures in Kuwait" which was read before the Iraq and Persian Gulf Joint Oversea Group in Kuwait.

Introduction

CORROSION seldom makes itself manifest early in the life of a structure. Since most of the oil-company installations in Kuwait are less than 10 years old, the effects of corrosion are not always obvious. This factor, coupled with the low annual rainfall, might lead to the conclusion that Kuwait conditions are non-corrosive, but the leaks which have been experienced and the reconditioning which has become necessary on buried pipelines would completely dispel such illusion. While there is little attack from the atmosphere, there is no doubt that most conditions experienced in Kuwait are corrosive, the only outstanding exception being structures that are in contact with crude oil. Up to the present the oil-side corrosion of tanks and pipelines has been negligible.

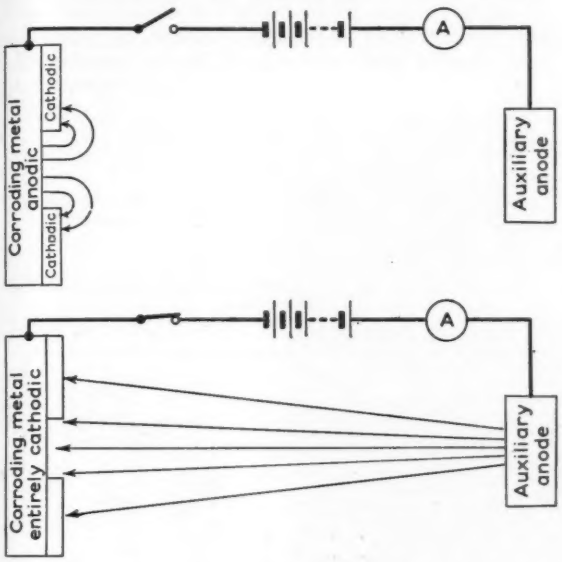
Cathodic Protection

Cathodic protection may be defined as the use of an impressed current to prevent or reduce the rate of corrosion of a metal in an electrolyte by making the metal the cathode. The source of the impressed current is immaterial. It may be supplied by a rectified alternating current, from a d.c. generator or it may be galvanic, i.e.

supplied by a more basic metal such as magnesium, zinc or aluminium.

In the United Kingdom it is only since the Second World War that any appreciable attention has been paid to the use of cathodic protection to prevent corrosion on underground and submerged structures. Since the early twenties when, as far as can be ascertained, initial systems were first installed in the United States, Belgium and Holland, the method has been gradually spreading over the whole world, and its effectiveness as a corrosion preventer is no longer in dispute.

Fig. 1 shows the current flow on a corroding specimen

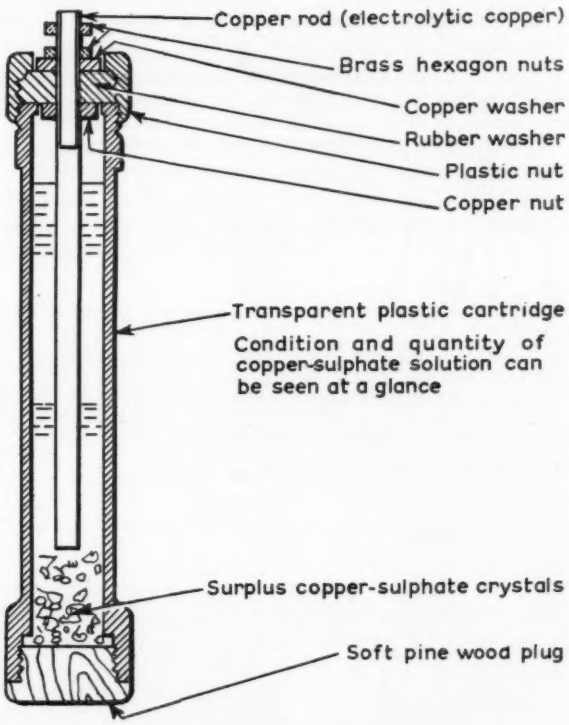


1 *Current flow in a metal system before and after the application of impressed current*

before and after the application of impressed current. On any corroding metal in an electrolyte anodic and cathodic areas exist with associated electric current flow between them; at the anodic area the metal undergoes chemical attack by the negatively-charged acid radical, while at the cathodic area a reducing action occurs and gases are liberated. If counter currents from any source are impressed on the corroding metal the chemical attack ceases. Thus cathodic protection depends upon the neutralization of all corroding currents. At the same time polarization occurs and, depending upon the electrolyte, causes the formation of hydroxide or other insoluble reaction products over the whole of the metal surface.

It has been found in practice that it is necessary only to decrease the potential of a ferrous metal to $-0{\cdot}85$ volt with respect to a copper-sulphate electrode (see Fig. 2) to obtain full cathodic protection. This is not true when the corrosion is caused by sulphate-reducing bacteria, and in this case it is necessary to depress the potential to at least $-1{\cdot}00$ volt with respect to a copper-sulphate reference electrode.

Cathodic protection may be applied to any metal in contact with an electrolyte, e.g. pipelines, internal surfaces of water-storage tanks, electric cables—the same principles apply in all cases.



2 *Copper-sulphate reference electrode*

Methods of Cathodic Protection

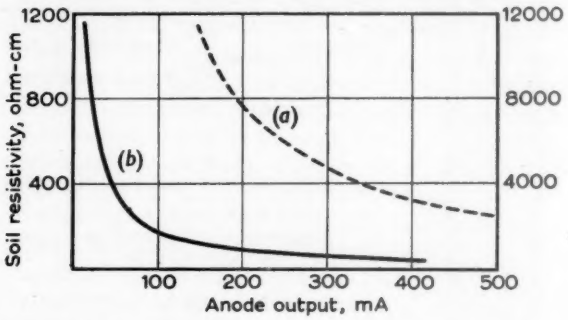
Galvanic anodes are composed of metals or alloys higher in the electromotive series than the metal to be protected. In general, magnesium of a suitable alloy is used but zinc and aluminium may also be employed. Fig. 3 (page 4) shows the variation of magnesium anode current output with soil resistivity. In some soils both zinc and magnesium anodes form insoluble salts which reduce the current output. This is usually overcome by the use of a special *backfill* consisting of gypsum, sodium sulphate and bentonite.

For structures requiring large electric currents, galvanic anodes are not usually practicable and a generator or rectifier is used, the current being delivered to the earth through an anode or system of anodes (Fig. 4) usually called a *ground bed*. These ground beds are normally constructed from scrap cast-iron or steel and are subjected

to severe corrosion. Graphite and silicon-iron anodes, either singly or in groups, are coming into increasing use for current distribution in cathodic protection systems. The advantage of these materials is their higher durability in soil conditions.

Cathodic Protection Schemes in Kuwait

On the many underwater and underground corrosion problems encountered on the oil installations in Kuwait, considerable use has been made of both methods of



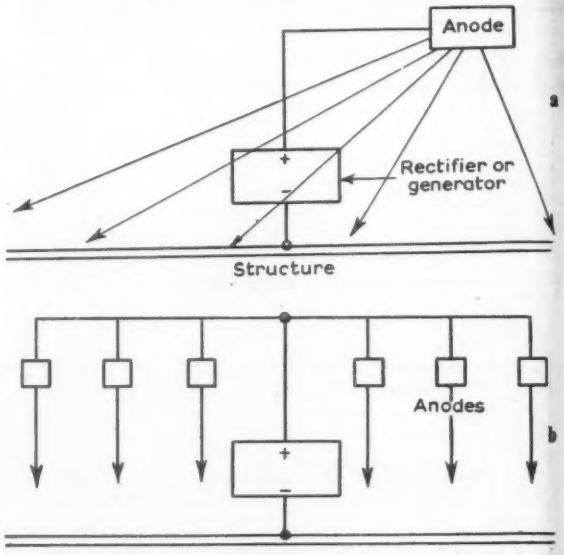
3 *Effect of soil resistivity on the current output from a magnesium anode*
(*a*) 0–1 200 ohm-cm. (*b*) 2 000–12 000 ohm-cm.

applying cathodic protection. The current density required to provide full cathodic protection has been found to vary from 5 mA/ft² of bare steel to as high as 20 mA/ft² in rapidly moving sea-water, the high current density in the latter being required because of the depolarizing action of the moving water.

The jetty at Mina-al-Ahmadi, shown in Fig. 5, which is believed to be the largest combined oil-loading and cargo-handling pier in the world, has presented a major corrosion problem. The pier was completed in December, 1949; it is an all-welded structure with timber decking and contains approximately 4 000 steel piles coated with coal tar. It consists of three main units, namely the approach pier, the oil pier and the cargo pier (which is also used to load crude oil) together forming an asymmetrical T-shape. The approach pier extends eastwards 4 140 ft from the shore. At the eastern extremity connection is made with the oil loading pier, which is 2 805 ft long extending to the north, and with the cargo pier extending 870 ft to the south.

The initial cathodic protection scheme was based on the use of magnesium anodes since sufficient generated power was not then available, and followed closely on the construction of the jetty. This scheme consisted of 270 hemispherical 200 lb anodes, like those in Fig. 6 (page 6), spaced to give a uniform current distribution throughout the structure. All the anodes were positioned on the sea bed, the lead wire being attached to a spool insulator underneath the decking. The wire was then taken to a junction box for anode-current measurement and for the insertion of resistance wire to control the anode current to the desired value. To provide full protection an initial average current of 0·96 mA/ft² of coated steel (0·45 amp per pile) was required; after polarization this was reduced to 0·40 mA/ft² (0·19 amp per pile) by insertion of resistance wire in each anode circuit. Corresponding anode currents were 6 amp and 2·5 amp respectively. The progressive deterioration of the magnesium anodes is shown in Fig. 7 (page 6), in which are four anodes of varying periods of service.

The initial scheme was designed for a three-year life; consequently in 1951 designs were prepared for a power scheme using rectified current. At present the approach



4 *Current flow through ground beds*
(*a*) Point anode. (*b*) Distributed anode.

section and a submarine line which passes through the approach section are protected by four large scrap-iron ground beds (approximately 10 tons each) spaced 400 ft from the structure and fed from 150 amp rectifiers located half-way along the approach section. The cargo pier and 900 ft of the adjoining section of the oil pier are protected by ground beds placed in the triangular space at the head of the approach section and also fed from 150 amp rectifiers. This location was chosen because there is no danger of cables being fouled by anchors. The remainder of the oil pier is protected by a further installation of magnesium anodes.

The Effects of Sea-Water

Cast-iron equipment for the conveyance of sea-water has presented a serious problem. Graphitization to the extent of 0·205 in. in 1·75 years and 0·51 in. in 3·5 years has been determined in the 44 in. cast-iron Class B

cooling-water mains (nominal wall thickness 1·08 in.). Such corrosion in a cast-iron pipe is usually associated with a tubercle—a mould of corrosion products that projects into the liquid, the centre of it being the anode of a local cell. A cathodic protection installation using graphite anodes has been installed on one section for test purposes.

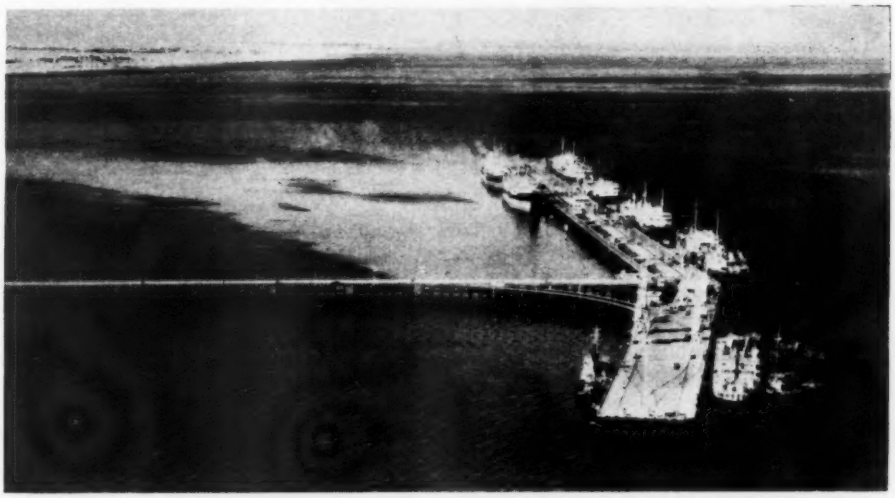
The original five pairs of 12 in.-diameter oil-loading submarine lines were all coated with a hot enamel approximately ¼ in. thick. When two pairs of these lines were taken out of service in 1950 after four years and pulled ashore, very severe corrosion was found. Pitting had taken place to depths of up to ¼ in. on many sections. This amply illustrates that protective coatings alone are insufficient to prevent corrosion in sea-water. On the remaining two pairs of submarine lines cathodic protection was applied, on one by magnesium anodes and on the other by a ground bed located at low tide and supplied with direct current from a motor-generator set.

On the more recently completed submarine lines (three pairs each consisting of 24 in.-diameter crude line and a 12¾ in.-diameter bunker line) a protective coating of hot enamel together with an inner wrap of Fibreglass, was used. Prior to launching, the coating and wrapping were tested with a high-voltage pin-hole leak detector, and any faults found were repaired until the coating was perfect. The cathodic protection system consists of 10- or 12-ton ground beds located at low tide approximately 200 yd from each line. Rectifiers of 150 amp capacity are located at the base of each line to provide the necessary d.c. supply. Provision has been made for increasing the number of rectifiers at each location in order to provide increased current as the coating on the line gradually deteriorates.

Underground Corrosion

The very nature of the rainfall in Kuwait, or for that matter in the entire Middle East, tends to promote the formation of electrolytic cells on a large scale. During thunderstorms rain falls at a rate greater than that of its absorption by the soil, and this, coupled with the general lack of vegetation, means that it runs off and collects in the valleys and depressions. In so doing the more soluble salts are leached from the soil and, on evaporation, are concentrated in the low-lying areas, thus forming salt flats. The salt flats remain more moist than the adjacent areas for the whole of the year, and, with their lower resistivity, form gigantic electrolytic cells in which the corrosion rate of a metal pipe is abnormally high.

The current flow in such a cell is from the pipe into the soil in the salt flat, through the soil to the adjacent higher-resistivity areas, into the pipe and through the metal of the pipe to the salt flat again.



5 *The jetty at Mina-al-Ahmadi*

Local Cells

Local cells may result from a myriad of sources, mostly being of the nature of non-homogeneity in the environment of the corroding metal. Perhaps in Kuwait the most common cause of the local cell is "gatch." This is a local term for a material comprising a mixture of gypsum, sand, clay and marl of variable proportions according to the location and the extent of weathering. Such cells would be in operation along the whole of the pipelines described above but their existence would be determined only by accurate measurements.

From the laws of electrochemistry it may be shown that a current of one ampere flowing continuously for one year at 100% efficiency involves the corrosion of 20 lb of steel. This is the weight of a block of metal one foot square and ½ in. thick—an insignificant quantity—but it also represents more than 5000 holes of ¼ in. diameter in a pipe of 0·28 in. wall thickness.

Corrosion Prevention by Cathodic Protection

The principle of cathodic protection, as explained

previously, may be applied to buried structures such as pipelines. In Kuwait a number of lines are so protected.

By the nature of the soil the current output from magnesium anodes is unlikely to be high except under favourable circumstances. In purely sandy areas the current output from the standard, 22 lb, packaged, backfilled type may be as low as 20 mA. In a salt flat a current of up to 500 mA may occasionally be obtained.

6 *200 lb hemispherical magnesium anodes used for cathodic protection of the jetty*

On the assumption that a current of 5 mA/ft² of bare metal is required for protection it is obviously virtually impossible to protect uncoated lines in an area such as Kuwait by magnesium anodes. However, a number of coated and wrapped steel lines have been successfully protected by this method.

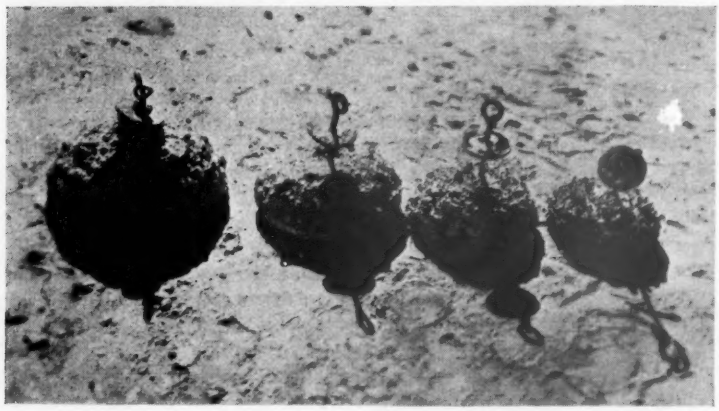
The first major buried pipeline to be cathodically protected in Kuwait was the 16 in. transit line from Magwa field to the Ahmadi tank-farm. It is 9·2 miles long and passes through a salt flat near its mid-point. With the location of magnesium anodes in the salt flat and the installation of insulating flanges (to prevent loss of current to adjoining pipelines) at the various centre manifolds and the tank-farm, this line has been under continuous cathodic protection since its construction. At present the current output varies from about 1·5 to 3·5 amp according to the season, and full protection is being maintained over the whole of the line. Such a low current demand speaks for the efficiency of the coating and of the pin-hole leak detector.

A more recent example is one of the newly constructed 34 in. gravity lines, approximately 5·4 miles long, which is being protected by a total of 0·25 amp from experimental centrally located anodes. The installed cost of these latter anodes is only about £100—the merest fraction of the cost of the line.

Cable Corrosion

A certain type of corrosion being experienced on cables in Kuwait is unique—certainly in its explanation if not in fact. It involves the proliferation of cellulose-decomposing bacteria on moist paper servings in contact with the lead sheath. The end products of the decomposition include carbon dioxide, which, acting on the lead, produces lead carbonate. These white corrosion products occur in pits which have, on at least one occasion, fully penetrated the lead and caused a cable fault. The full explanation of this particular type of corrosion is not as yet available.

In common with all buried steelwork the armour of cables suffers corrosion in some localities at a very appreciable rate.



7 *Progressive deterioration of the anodes*

Acknowledgment

Thanks are due to the management of the Kuwait Oil Co. for permission to publish this article.

CHEMICAL GENERATION AND STORAGE OF ELECTRICITY

The generation of electricity by the electrochemical oxidation of carbon and hydrogen was studied intensively during the nineteenth century. Interest has lately been revived in the process since it may lead to higher efficiency in the use of increasingly precious fuels. The author is with the Research Laboratories of the Central Electricity Authority where he has been responsible for the work on fuel cells.

By A. M. ADAMS, M.A., A.Inst.P.

THE use of electrochemical processes for generating and storing electricity is familiar in such applications as dry-cell hand-lamps and car accumulators, but up to the present similar principles have not been applied to generation or storage on a larger scale, owing to economic limitations. There are several reasons for this, among them the cost of, and the energy losses involved in, extracting metals from their ores for use in primary cells, and the capital cost, weight and bulk of lead accumulators. In theory, however, a primary cell could be based on the electrochemical oxidation of any substance that is thermodynamically unstable in the unoxidized state. The only materials found naturally in large quantities that are capable of being oxidized with comparative ease are fuels, e.g. coal, oil and natural gas. Hence, for large-scale generation by electrochemical processes, cells must be developed capable of oxidizing fuels either directly or indirectly. Such cells have come to be known as fuel cells, and were the subject of much investigation during the nineteenth century. Interest has been revived in the possibility of developing them as an alternative to existing methods of converting the chemical energy of fuels into electrical energy, owing to the world-wide expanding demand for electricity and the increasing cost of fuels. Several reviews of the subject have appeared in recent technical literature.[1, 2, 3]

At present, thermal power stations convert not more than two-fifths of the heat of combustion of fuel into electrical energy, the balance being rejected as low-grade heat, which in most instances has no realizable value. This is partly due to the fundamental thermodynamic limitations of ideal heat engines working between practicable temperature limits, and partly because economic design results in efficiencies considerably below that of ideal engines. As a result of advances in metallurgical and engineering techniques, the temperature limits and the economic level of efficiency increase steadily from year to year, but there is little prospect of any rapid advance in these directions.

On the other hand, in theory at least, electrochemical techniques offer the prospect of reaching much higher efficiencies if certain obstacles can be overcome. The basic problem is to speed up the chemical reactions involved, e.g. by increasing the temperature, pressure and surface area of the reactants and by using catalysts, until they can be carried out economically on a large scale. Before dealing with these researches, it will be worth while to examine some of the principles involved.

Thermodynamic Principles

The overall chemical reactions that take place during the oxidation of a fuel are similar, whether they occur in a combustion chamber or an electrochemical cell. For practical purposes the bulk of natural fuels may be regarded as being composed only of carbon and hydrogen, the oxidation of which can be represented by two reactions.

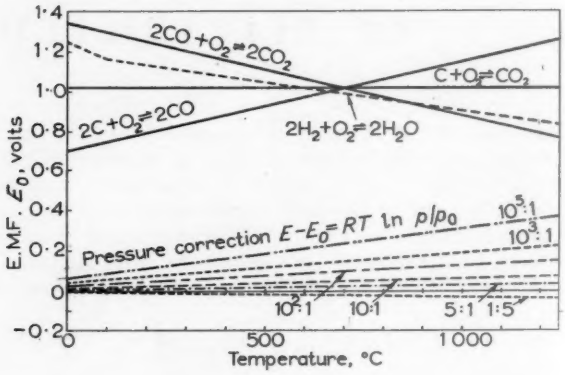
$$C + O_2 \rightleftharpoons CO_2 \quad . \quad . \quad . \quad . \quad (1)$$
$$2H_2 + O_2 \rightleftharpoons 2H_2O \quad . \quad . \quad . \quad . \quad (2)$$

When a chemical reaction such as either of the above occurs, useful work may normally be obtained, together with some evolution or absorption of heat. If the reaction is carried out under thermodynamically reversible conditions, the maximum amount of useful work will be obtained. This will be equivalent to the difference in chemical free energy between the reactants and the products. However, in most instances the change in free energy will be less than the heat of combustion. Equation (1) is exceptional in this respect, since ideally over 99% of the energy degraded into heat during combustion could be converted directly into useful work by carrying out the reaction electrochemically. A fuel cell based on this reaction is therefore particularly attractive. The hydrogen/oxygen reaction is less satisfactory, the maximum amount of work obtainable between 0 and 1 250° C decreasing from 95% to 66% of the heat of combustion.

In any real cell, in order that the reaction should proceed at an appreciable rate, there must be some degradation of free energy into heat and the useful work obtainable will be correspondingly reduced. It may be possible to convert a fraction of this heat into useful work by means of a heat engine.

The change in free energy also determines the electro-

motive force corresponding to the cell reaction. The variation of e.m.f. between 0 and 1 250° C under standard conditions is shown for several reactions of interest in Fig. 1. These standard conditions assume that both gaseous reactants and products are present at a pressure



1 *Variation of cell e.m.f. with temperature for various reactions under reversible conditions*

of one atmosphere (more precisely, unit fugacity). The effect on the e.m.f. of departing from this standard pressure can be found by means of the correction curves at the base of Fig. 1. It will be seen that even if the concentration of products is so reduced that the ratio of pressure of the reactants to the pressure of the products is 10^5 : 1, the e.m.f. is increased by only 0·07 volt at 0° C or 0·37 volt at 1 250° C. On the other hand, if the fuel gas in a cell contains only 1% of combustible matter (e.g. hydrogen and carbon monoxide, corresponding to a calorific value of about 3 B.t.u./ft^3), the cell's e.m.f. would be reduced by only 0·03 volt at 0° C or 0·15 volt at 1 250° C, whilst the effect of using air instead of oxygen would be almost negligible, as far as the reduction of e.m.f. is concerned.

It will be noted that the e.m.f. of a hydrogen/oxygen cell increases more rapidly as the temperature of reaction falls below 100° C, owing to the formation of water in the liquid rather than the gaseous state. If a hydrogen cell is operated at pressures above atmospheric, this advantage can be obtained, even at temperatures above 100° C, and this will more than compensate for the fall of the standard e.m.f. as the temperature is increased. The increase in e.m.f. does not represent any gain of energy, however, since at least the equivalent amount of work must be done to compress the gases supplied to the cell.

In addition to the data for reactions (1) and (2) above, Fig. 1 shows that the e.m.f.'s for the two partial reactions $C \rightarrow CO$ and $CO \rightarrow CO_2$ are of the same order as for reaction (1), but that the e.m.f. of the first increases with temperature, while that of the second decreases. The energy available from either reaction by itself will vary between 40 and 60% of that from reaction (1) in the temperature range under consideration.

Cell Design

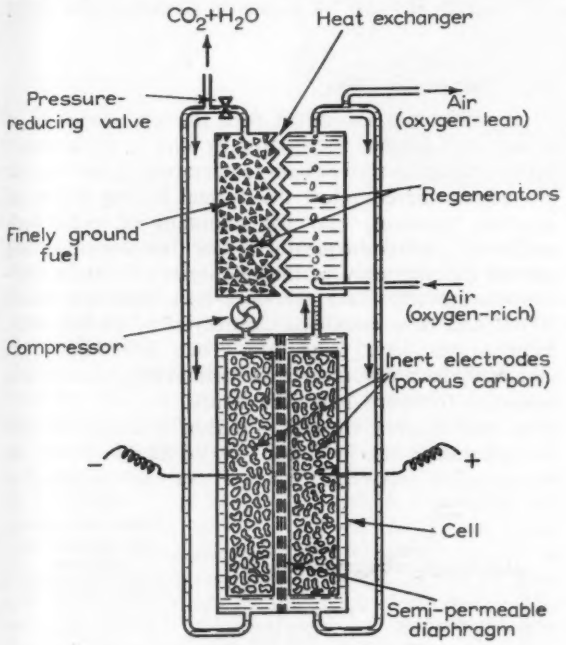
The essentials of an electrochemical cell are the electrolyte and two electrodes; in fuel cells these will be oxygen and the fuel, or derivatives from them. The electrolyte must prevent direct reaction between the fuel and oxygen or their secondary products, and as carbon does not ionize under practicable operating conditions, the electrolyte in a carbon/oxygen cell must be capable of transferring oxygen to the fuel electrode by ionic migration. For efficient operation it is essential that this process should continue only as long as the electrodes are connected externally by an electrically conducting circuit. As soon as this circuit is broken the electrodes should assume the reversible potential difference appropriate to the reaction and the conditions of operation. In principle, the electrolyte may be gaseous, liquid or solid, but recent research[4] suggests that only aqueous solutions or fused salts are likely to be of any practical value. In all types of cell it is advantageous to use electrodes of large surface area (usually porous), to place these close together and to circulate the electrolyte.

An extensive literature dating from the time of Sir Humphry Davy's experiments in 1801 has now grown up dealing with fuel cells. It is not possible to review this adequately here and for a discussion of the earlier work Howard's review[1] in particular may be consulted Some authors have classified fuel cells into direct and indirect types, but the method adopted below is to consider first the cells using aqueous electrolytes below 250° C and then various high-temperature cells. The low-temperature types consist of redox and hydrogen cells, and although many others have been proposed, such as those based on reactions with halogens instead of oxygen, none appears to be of any practical importance.

The Redox Cell

The name given to this type of cell derives from the use of the abbreviation "redox" for "reduction-oxidation," as applied to certain types of chemical reaction. From the broader chemical point of view reduction is equivalent to the loss of electrons and oxidation to the gain of electrons by a molecule, atom or ion. In redox cells, suitable atoms or ions are alternately oxidized and reduced, generally in aqueous solution; the cell proper may be regarded as two half-cells in each of which the only mechanism involved is the transfer of electrons between the atoms or ions of the electrolyte and the inert electrode. The electrolytes in contact with the anode and cathode of the cell are called the *anolyte* and *catholyte* respectively. Each of the solutions is continuously circulated through ancillary apparatus, in which, by reaction with either the fuel or atmospheric oxygen, the concentration of solute atoms or ions present before contact with the electrode is restored. As one electrode gains electrons and the other

loses them, a potential difference will exist between the electrodes, which can be partially maintained across an external load as long as the regeneration processes continue. It is probable that heat would be evolved during the regeneration of the anolyte with oxygen and absorbed during the reaction of the catholyte with the fuel. This represents a loss of efficiency that could be reduced by suitable provision for heat exchange. Means must also be provided for the interchange of hydrogen and hydroxyl ions between the anolyte and catholyte, but interdiffusion of the respective solute matter must be prevented as far as possible. Probably an ideal answer to this problem cannot be achieved, but reasonable success has been attained using various forms of semi-permeable diaphragm. A redox cell can therefore be represented



2 *Redox cell (diagrammatic)*

schematically by Fig. 2. The pressure in the catholyte regeneration apparatus is increased by means of a pump, so that the temperature of oxidation of the coal may exceed 100° C.

Two chief advantages are claimed for this system to offset its complexities. Many inorganic ions readily lose or gain electrons, so that it should be possible to choose reactions for each half-cell that will proceed without much degradation of energy. Secondly, the reactions with the fuel and air or oxygen can be carried out independently and each under the optimum conditions. For instance, if coal is to be used to regenerate the catholyte, it can be ground and suspended in the solution to provide the maximum surface for reaction; the possibility of increasing the temperature and pressure has already been mentioned and catalysts can also be employed. An important further advantage would be the relative ease with which inert mineral matter could be removed from the system.

Some preliminary results of experimental investigations supported by the Central Electricity Authority at King's College, London, under the direction of Sir Eric Rideal, have recently been published.[5] From this report it is clear that some of the obstacles have been overcome, at least on a laboratory scale. For the anolyte, the bromine/bromide system appears to be suitable; the transfer of electrons from an inert carbon electrode to the bromine molecule, forming Br^- ions, proceeds smoothly and with only a small energy loss. Also a method of regenerating the bromine from hydrogen bromide by atmospheric oxygen has been evolved, using a nitrogen peroxide catalyst.

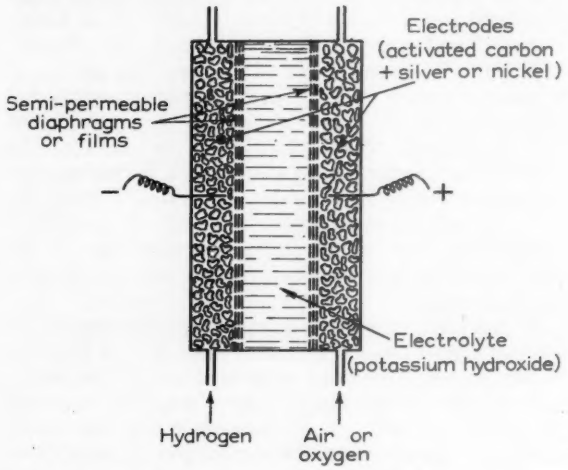
On the other hand, less success has been attained on the fuel side of the cell. The stannous/stannic system was chosen as being the most suitable. Even so, the energy loss during the electrode reaction was approximately equivalent to a 20% loss of efficiency in this stage alone. Moreover, reduction of the stannic ion by solid fuels proved to be difficult, even at elevated pressure and temperature (160–180° C), only 15% of the carbon initially present being oxidized. By using alternative redox systems, such as that formed by ferrous and ferric ions, up to 30% oxidation could be reached and activation polarization at the carbon electrode was also less severe, but on theoretical grounds it can be predicted that these stronger oxidizing agents will result in the overall e.m.f. of the cell being reduced. That this would involve an even more serious loss of free energy appears to be confirmed experimentally.

The cell described by Posner had an open-circuit voltage of 0·91 volt, the theoretical e.m.f. for the C/CO_2 reaction being 1·02 volts (cf. Fig. 1), and with a current density of 20 amp/ft² the output dropped to 0·5 volt. In these experiments fresh electrolyte was continuously supplied to each electrode, no attempt being made to regenerate the spent solutions.

Hydrogen/Oxygen Cell

In contrast to carbon, hydrogen ionizes even at ordinary temperatures, and although oxygen does not ionize as readily as might be desired, a direct hydrogen/oxygen cell with aqueous electrolyte can be set up at room temperature. At 25° C the reversible e.m.f. corresponding to reaction (2) is 1·23 volts under standard conditions. Cells of this kind have been investigated more or less continuously for over a century. Recent improvements made in the Soviet Union were described by Davtyan in 1947; the resultant cell is shown diagrammatically in Fig. 3 (page 10). Active carbon electrodes with nickel and silver as catalysts and other metals or oxides as promoters were employed. This cell gave an output of 0·75 volt at a current density of 32 amp/ft² (referred to the electrode area), but no indication of durability was given.

A difficulty that arises with all cells having gaseous electrodes and liquid electrolytes is to prevent the latter wetting the surface of the solid material that must be provided to conduct electrons to and from the gas



3 *Low-pressure hydrogen cell (Davtyan, 1947)*

molecules. If the solid becomes covered with a liquid film, access of the gas molecules will be hindered. In Davtyan's cell the electrodes were waterproofed by means of a wax film, which was presumably thin enough to act as a semi-permeable membrane. As the film must be resistant to the caustic electrolyte, durable wax films are difficult to prepare. Silicone-varnished glass-cloth diaphragms have been tried in place of the wax films and had a life of several months, but the internal resistance was increased to at least 20 times that of Davtyan's cells. Moreover, the open-circuit voltage was only 0·73 volt instead of 1·12 volts as in the Russian experiments.

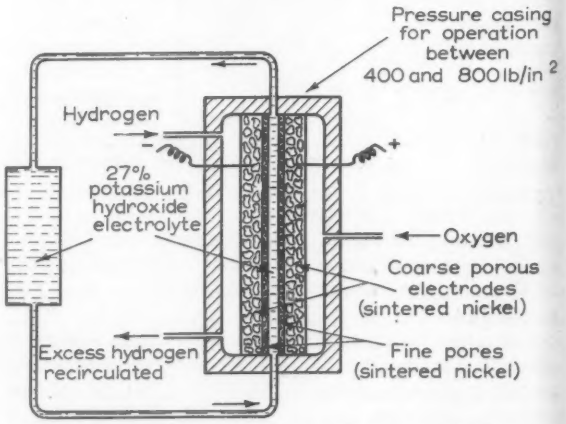
A successful answer to many of the difficulties associated with hydrogen cells has been found in the high-pressure type developed by F. T. Bacon and his associates at Cambridge.[2,6] This work is jointly supported by the Electrical Research Association and the Ministry of Fuel and Power. The cell is shown schematically in Fig. 4. The porous electrodes are made by sintering nickel powder and consist of a relatively coarse porous material (pore size about 30 μ), coated with a thin layer having fine pores (less than 16 μ) on the surface in contact with the electrolyte. The hydrogen and oxygen are supplied to the rear of their respective electrodes under a differential pressure of about 2 lb/in.^{2}, which is sufficient to prevent the electrolyte penetrating beyond the fine pore layer, but not so high that the gases bubble into the electrolyte. No membranes are therefore required and the large internal surface of the pores is available for the reactions between the gas molecules and ions, the electrode and the electrolyte. Still higher reaction rates have been reached by increasing the total pressure to between 400 and 800 lb/in.^{2} and the temperature to between 140 and 240° C. Water formed during the cell reaction is evaporated from the rear of the hydrogen electrode by circulating the gas over the surface, condensed externally and drawn off at intervals.

This cell had an open-circuit voltage of 1·05 volts at 240° C and 800 lb/in.^{2}, compared with a calculated value of 1·17 volts for the reversible e.m.f. under these conditions. Even at 1 000 amp/ft^2, an output of 0·6 volt could be obtained, and at 250 amp/ft^2 the output was 0·85 volt. This probably corresponds to about 2 kW/ft^3. Under the conditions mentioned, fairly rapid corrosion of the oxygen electrode occurred, but by improvements in the method of making this electrode and by reducing the operating temperature to 200° C and the pressure to 600 lb/in.^{2}, cells have been produced capable of operating for hundreds of hours.[6] A battery of six cells is illustrated in Fig. 5.

High-Temperature Cells

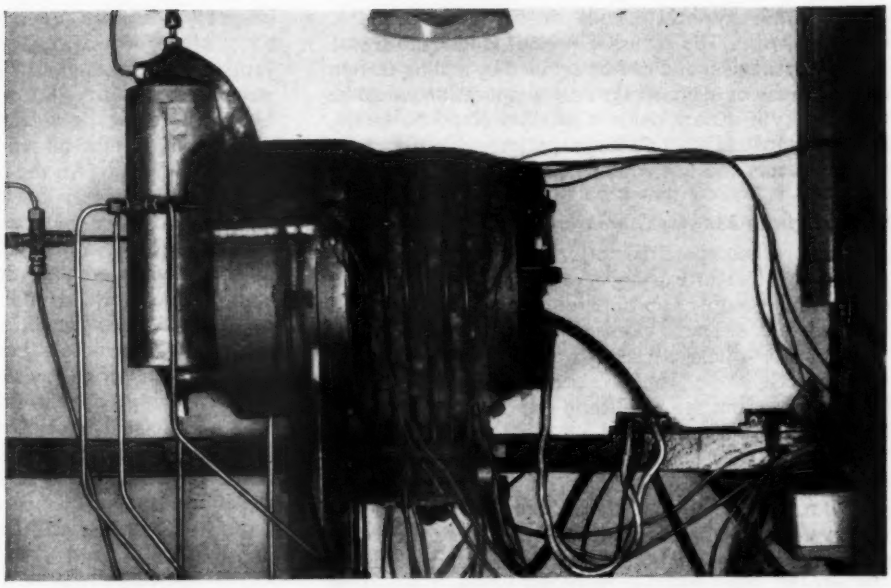
The difficulties associated with the low reactivity of carbon and gaseous fuels naturally lead to experiments being conducted above room temperature. Little success has been achieved below the normal boiling points of aqueous solutions, and the adoption of even high pressures, and consequently higher temperatures, has proved effective only in the hydrogen cell. Most high-temperature cells have therefore been operated above 500° C and have employed electrolytes of molten salts. Many types have been tried, but difficulties have invariably been encountered in maintaining such cells in operation for more than a few hours.

In 1937, to avoid the lack of durability associated with molten electrolytes, Professor Baur of Zürich introduced the so-called solid electrolytes. These were mixtures of



4 *High-pressure hydrogen/oxygen cell (Bacon, 1952)*

oxides that were supposed to have sufficient ionic conductivity below their melting points to function as electrolytes. The most effective composition was found to be a mixture of impure ceric and tungstic oxides with some

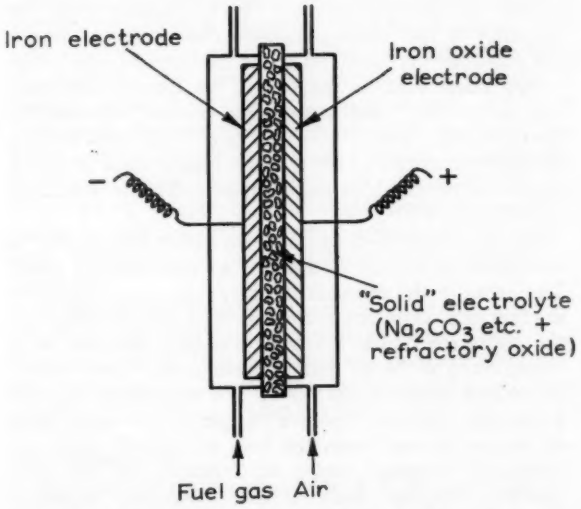


5 *A battery of six hydrogen/oxygen cells constructed by F. T. Bacon*

clay to improve the ceramic properties. The oxygen electrode consisted of iron oxides; in some experiments carbon was used directly as the fuel electrode, but it was suggested that in large-scale operation, producer gas or water gas would be used, with a mixture of iron and iron oxide as the electrode. To obtain a sufficiently high conductivity the operating temperature had to exceed 1000° C; this and the instability of the tungstic oxide were obstacles to further development of these cells.

Improvements in this type of cell have also been made in the Soviet Union by Davtyan; alkali carbonates and glass were added to the electrolyte and it was found possible to reduce the operating temperature as low as 600° C, optimum results being obtained at 700° C. Iron and iron oxide were again used as electrodes for the fuel gas and the oxygen respectively, as in Fig. 6. On open-circuit, a cell of this type gave 0·85 volt at 700° C, operating on carbon monoxide and air. At a current density of 30 amp/ft^2 the output voltage was 0·75 volt; this suggests that an output of 350 watts/ft^3 might be attainable.

Investigations on similar lines have been reported from the United States, Germany and Holland, and work is also being done in this country. During the experiments at Amsterdam, it proved possible to repeat and improve upon Davtyan's results.[4] Moreover, cells were kept in operation for over a week without deterioration, with coal gas, carbon monoxide or water gas as a fuel. In some of the German and Dutch cells, the carbonate electrolyte was held in the pores of a ceramic plate and it now appears to be generally accepted that, under working conditions, the "solid" electrolyte consists of a molten salt or eutectic mixture of salts, together with a matrix of solid material. The function of the solid matrix is to prevent deformation of the electrolyte and absorption of the liquid matter in the electrodes. These electrolytes are therefore fundamentally similar to



6 *High-temperature gas cell with "solid" electrolyte (Davtyan, 1947)*

those prepared by absorbing the fused electrolyte in a rigid porous ceramic material.

The use of alkali carbonates as electrolytes implies that oxygen is transported from the oxygen electrode to the fuel electrode in the form of carbonate ions (CO_3^{2-}), and in order that the supply of carbonate-ion carriers be maintained, carbon dioxide must be allowed to diffuse

back to the oxygen electrode or be made available there otherwise. The diffusion process is likely to retard the cell mechanism and can be avoided by adding carbon dioxide to the oxygen supply. This complication would be unnecessary if a pure oxide electrolyte could be found, but unfortunately most stable oxides have extremely high melting points and low conductivity as solids.

Characteristics and Applications of Various Types of Cell

In order to compare the performance of various types of cell with that of existing methods of generation and storage, it would be appropriate to consider a lead-acid accumulator, a Diesel-electric generator and a power station for the public electricity supply. In some instances the fuel cell alone would not completely replace the existing plant, but some indication of economic substitutions can be obtained.

According to a standard work on storage batteries, current densities of 8–10 amp/ft^2 are normal in traction cells during discharge at the 5-hour rate; in practice these values may be exceeded by a factor of 2 or 3 and a starter battery might operate for short periods at 500 amp/ft^2. For complete batteries power outputs of 252–288 watts/ft^3 are suggested. The energy efficiency could be as high as 85%. Unfortunately, no comparable estimates of energy efficiency are available for fuel cells, but the efficiency could not exceed the ratio of output voltage to theoretical e.m.f. It is believed that the efficiency of the Bacon cell approaches this ratio closely, but for other types of cell it may be considerably lower.

For Diesel-electric generators the thermal efficiency may reach 40% and the power output 140 watts/ft^3. Conventional power stations are now approaching thermal efficiencies of 40%, and a typical value of power output for the combination of boiler and turbo-alternator would be 1 kW/ft^3.

On its present performance, the redox cell cannot be considered a serious competitor to conventional plant. The losses in the regeneration processes, particularly on the fuel side, represent at least 30% loss of efficiency, and if it is assumed that a fuel cell is 60% efficient (as it would have to be to make development worth while), the output from the cell would be considerably less than 8 watts/ft^3. The two regenerating plants are each likely to occupy several times the bulk of the cell itself and expensive materials would be required for the plant handling bromine. Some of these objections would be less serious if means could be found of accelerating the reaction between the fuel and the stannic ion or of reducing the activation polarization at the negative electrode.

The performance of the high-pressure hydrogen cell is so much superior to the low-pressure type that the latter can be disregarded. Even so, the cost of preparing hydrogen from coal or coke renders it unlikely that at present any type of hydrogen cell would be economic for generating purposes. Theoretically, hydrogen can be made from coal or coke via the water-gas reaction with hardly any loss of free energy. In practice, the thermal efficiency of plant for this purpose does not exceed 55%. Moreover, expensive purification processes would probably be necessary to preserve the electrolyte and electrodes in the cell from rapid deterioration. Pure hydrogen might be available, for example, as a by-product of certain oil-refinery processes, but the real field of application for the hydrogen cell seems to be as a storage device, especially where high energy/power ratios are involved, since the size of the cell is governed by the maximum-power rating and not by the amount of energy to be stored. Moreover, the Bacon cell can operate at considerable overloads if some sacrifice of efficiency can be tolerated. This characteristic would be of great value for traction purposes. Less probably, hydrogen cells might be used for energy storage in conjunction with the electricity supply system. In either instance, the efficiency of the associated electrolysers would have to be taken into account and at present this is lower than is desirable. However, if an electrolyser could be designed to operate under conditions of temperature and pressure similar to those in the Bacon cell, the efficiency might be greatly improved.

The equivalent energy-storage capacity of hydrogen and oxygen compressed into steel cylinders at 100 atm is about 4 kWh/ft^3. For a 5-hour storage period and assuming that 70% efficiency is attainable at the power output of 2 kW/ft^3 mentioned above, the effective storage capacity would be equal to 2 kWh/ft^3 compared with 1·4 kWh/ft^3 for lead-acid accumulators. For applications requiring longer storage periods, the Bacon cell would compare even more favourably with the accumulator. However, some reduction of the figure of 2 kWh/ft^3 might be necessary to secure adequate durability of the electrodes.

The high-temperature gas cell is the only type that appears to have any possibility of application to large-scale generation, particularly as it seems that as a result of recent improvements better performance figures may be attainable than have been quoted above. However, it would be unduly optimistic to compare even the figure of 350 watts/ft^3 with 1 kW/ft^3 for a typical power station and to assume that this could be attained at an efficiency of say 60%. In this country at least, there seems to be no possibility of a ready-made gaseous fuel being available at an economic cost and plant to manufacture it from coal or oil would probably occupy several times the volume of the cell itself. Moreover, most of the ancillary plant provided at power stations would still be required. However, if the efficiency is considerably higher than in present-day stations, no cooling plant would be needed, and in some circumstances this would represent a large saving in space and cost.

It would not be economic to operate such a system by making producer gas from coal, because at 700° C only half the energy available from the $C \rightarrow CO_2$ reaction can be obtained from the $CO \rightarrow CO_2$ reaction. This difficulty could be overcome in two ways. In the first of these the gas generator would be operated initially as a conventional producer-gas plant, but once the cells were

operating at full output, half the CO_2 formed in the cells would be recirculated through the fuel bed, where it would be reduced back to CO:

$$C + CO_2 \rightleftharpoons 2CO \quad . \quad . \quad . \quad . \quad (3)$$

The carbon monoxide formed would, of course, be supplied to the fuel cell.

As an alternative to this gasification process, the water-gas reaction could be employed:

$$C + H_2O \rightleftharpoons CO + H_2 \quad . \quad . \quad . \quad (4)$$

This equimolecular mixture of carbon monoxide and hydrogen could be used in the fuel cell, probably without any alteration in characteristics.

Either of these reactions could theoretically be carried out at about 700° C with negligible energy loss, but in practice reaction rates would be too slow to be economic. It would probably be necessary to raise the temperature in the gas generator to about 900° C, to accelerate the reaction. Various means have been suggested whereby the heat generated in the fuel cells by irreversible processes could be employed for this purpose. No completely satisfactory solution to this problem has been discovered if the optimum operating temperature of the cells is 700° C, i.e. about 200° C below the temperature at which heat must be supplied to the gas generator. It is evident, however, that the method to be adopted of gasifying solid or liquid fuels must be considered an integral part of the design of fuel cells for large-scale generation. Of course, this problem would not arise in connection with a cell working on natural gas; at present there is some doubt whether methane and other hydrocarbons could be electrochemically oxidized, but there seems to be no *a priori* reason why this should not be possible. If necessary, catalytic decomposition and partial oxidation to carbon monoxide and hydrogen should be practicable.

Conclusions and Possible Developments

As far as the knowledge at present available indicates, no low-temperature fuel cell suitable for generating electricity on an industrially significant scale seems likely to be developed for many years. The high-pressure hydrogen cell designed by F. T. Bacon has reached the stage at which application as an energy-storage device can be considered. In this field it is more likely to extend the scope of electrical storage to larger units and longer durations than at present, than to replace existing types of storage battery.

Recent research has resulted in improvements to high-temperature gas cells and it is believed that problems associated with the durability of cell components have been at least partially solved. This work has not yet reached the development stage and therefore no practical application of this type of cell is likely for several years at least.

There is a lack of data for all types of cell, which hinders any economic assessment of their possibilities. For instance, overall energy efficiencies have only rarely been measured and there is practically no information available on the costs of construction. With the possible exception of nickel electrodes used in the Bacon cell, no very expensive materials are likely to be required and the absence of rotating machinery will probably be a favourable factor in relation to capital costs. However, any potential advantage this might have on maintenance costs could be offset by corrosion due either to the use of caustic alkalis in the Bacon cell or high operating temperatures in the other types.

The output from a fuel cell is low-voltage direct current. For public supply this would almost certainly have to be converted to alternating current for transmission and distribution. Assuming that generation was at between 500 and 1 000 volts by a series connection of cells, the technical problems of inversion could be surmounted, probably by means of static inverters, but this would add to the complexity and cost of the system. It seems probable, therefore, that the initial applications of fuel cells will be to electric traction and to electrochemical and electrometallurgical processes, for which low-voltage direct current is required. The possibility of developing processes of this type might be of great economic advantage to this country.

In view of the likely rate of development of fuel cells and of the recently published plans for electricity generation from nuclear energy, it might seem that fuel cells would be obsolescent before they could reach a stage of practical application. However, the present indication is that there will be a period of many years before nuclear-energy plant can carry the burden of the cumulative annual increase in electricity consumption. As it is apparently impracticable to mine more coal and the mean annual improvement in thermal efficiency is insufficient, plans have had to be made to rely on imported oil fuel. If fuel cells could reduce the requirements for this import, the comparatively small expenditure on research in this field would be justified many times over.

Moreover, by suitable choice of reactions, electrochemical cells could be employed to convert heat into electrical energy. It is therefore not inconceivable that they might be used in conjunction with nuclear reactors instead of conventional heat engines.

Acknowledgment

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NEW INDUSTRIAL INSULATING MATERIALS

The physical properties of traditional insulants are often inadequate to meet the requirements of modern electronic equipment, and in this article the authors, who are with the Research Department of the Metropolitan-Vickers Electrical Co., briefly review some new dielectrics which have been discovered in recent years.

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THE main insulating materials used in power engineering are still basically the same as they were half a century ago, although great improvements have been made in some of their characteristics. Mica, paper, light mineral oil and porcelain, for instance, are indispensable at present for the insulation of alternators, bushings, transformers and outdoor equipment. There are various possible alternatives but they are rarely as suitable, and often more expensive, and at the moment it is difficult to see what new products a chemist can hope to offer which will completely replace any of these materials.

When, however, we turn to the physical and electrical requirements of the insulation of airborne and communication equipment, we find that many of the conventional materials are completely useless—either because their properties suffer at the extremes of temperature which are experienced, or because their dielectric losses are quite intolerably high at radio frequencies. Hence it is not surprising that it is in this field that the greatest progress has been made in the development of new materials; their required bulk is usually small and their cost, therefore, is of smaller importance than that of materials for power-frequency equipment.

When an insulator is tested in the laboratory the measured electric strength is found to be perhaps several thousands of volts per mil; it is thus at first sight astonishing that the working stress in power-frequency plant is often only 40 or 50 volts per mil and that the apparently large factor of safety is not sufficient to prevent occasional failures in service. Therefore, before considering any new materials we may usefully ask, first, why this should be so; secondly, what the disadvantages are of the present materials, and thirdly, what characteristics we should like in any substitutes. A short answer to the first question is that the prolonged application of stress may, and usually will, result in degradation of the material by processes which are of little or no importance in short tests and which have no significant influence on the results of such tests.

There are many answers to the second question:

Non-uniformity of thin films may make it impossible to utilize the high electric strength of such materials.

Inhomogeneity of the insulation will give rise to voids with consequent internal discharge.

Penetration of moisture will cause increased losses and reduced electric strength.

Chemical degradation may occur at high temperatures, with consequent reduced electric strength, and mechanical deterioration.

The answer to the third question is almost implicit in the answer to the second. We require the best mechanical properties and the highest heat resistance obtainable, mechanical stability, resistance to discharge (if this cannot be eliminated), and low losses, especially at high frequencies.

Let us now look at a few new materials and see what advantages they offer over their predecessors.

Wire Enamels

The enamels used for coating wire were formerly of the oleo-resinous type; their mechanical properties were not very satisfactory and they were often dissolved by the impregnating varnishes. They have now been partly replaced by synthetic enamels, one of which, based on resins of the polyvinyl acetal and phenolic types, combines flexibility with exceptionally good resistance to abrasion and in addition may be used with all kinds of impregnating varnish. Care may be necessary, however, to prevent undesirable physical effects of solvents.

The epoxy resins (of which Araldite is one trade name) possess very good electrical and mechanical properties combined with excellent resistance to thermal ageing; the latter characteristic is also displayed in a marked degree by the polyurethane compounds, which are now attracting attention as wire coverings and for other applications.

Mica

Mica is at present irreplaceable as a constituent of alternator slot insulation because all other materials which can be applied for that purpose suffer more or less rapid chemical and thermal degradation as a result of exposure to corona discharge. The supplies of mica, however, are sometimes of inferior quality and experiments have been in progress for some time on the manufacture of mica paper. This consists of extremely small mica flakes forming a suspension in water and made up into mica sheets in a manner very similar to the method adopted for the manufacture of ordinary paper. These sheets are more uniform and have a higher electric strength than the laminated product, but on the other hand they cannot be manipulated without breaking and consequently they require a backing sheet, preferably of some inextensible material such as glass fabric. Encouraging results have been obtained and the cost of the new material rather than its characteristics may prove to be the decisive factor in its development.

Solventless Varnishes

The obvious drawback to the ordinary varnishes is that the removal of solvents during drying necessarily causes the formation of voids. Solventless varnishes have been produced in which the varnish base is fluid without the presence of solvents, and one important type is based on the thermosetting oil-modified phenolic resins. This type has some undesirable properties, however, such as long drying time and high power factor, especially at high temperatures. A more promising development is a thermosetting material based on polyester resins which is liquid at room temperature and can be rapidly cured at about 125° C. The special precautions which have to be taken in the storing and application of this varnish, however, have hampered its commercial use.

Casting Resins

The polyester and epoxy resins may also be used as castings and may take the place of taping, which is expensive and electrically unsatisfactory. Shrinkage of the polyester resins has been largely overcome by the use of mineral fillers.

Silicones

The advent of silicones in various forms must be regarded as an outstanding advance in the technology of insulation. The replacement of the carbon chains of pure organic compounds by the silicon–oxygen chains in the silicones has led to the production of a range of solid and liquid materials akin to the conventional organic materials but capable of withstanding much higher temperatures without deterioration.

Their electrical properties are good and a substantial increase in the operating temperature of electrical equipment is permitted by their use. On the other hand, the mechanical properties of the solid silicones are not always very satisfactory and the price is at present inconveniently high.

The most promising field of application of these materials is for the insulation of equipment where it is important to keep down the size or where the apparatus is subject to occasional very heavy overloads.

Low-Loss Polymers

This group includes some of the most important and interesting materials which have been produced in recent years.

Polythene is now so well known that it is sufficient to refer only briefly to its properties. Its extremely low power factor at high frequencies has made it of immense value in radar equipment; its chemical inertness (except in hot oil), flexibility and toughness have added to its value, but its rather low softening point (110° C), which makes it easy to mould, has also prevented its use at high temperatures. Some improvement in this characteristic has been effected by electronic bombardment and recent German developments (so far unpublished) suggest that by suitable processing both the resistance to oil and the softening point can be substantially increased.

The electrical characteristics of polythene would appear to make it the ideal dielectric for very-high-voltage power cables; but polythene does not resist discharge at all well and its high contraction on cooling, and the resultant difficulties which arise in the construction of a cable without voids, have so far prevented its use except at voltages of a few kilovolts.

Polystyrene has similar electrical properties to polythene but, although more rigid when cold, it softens at a lower temperature (75° C) and is liable to crack. Films 0·5 mil in thickness have been produced and applied on a limited scale to the manufacture of small radio capacitors, and it might be expected that the extension of the use of this material to large power-frequency capacitors would be attended by quite substantial economies in size. The cost of such films, however, is at present very high and serious practical difficulties still require to be overcome in the winding of the elements. For example, polystyrene does not wrap as easily as paper and wrinkling is troublesome, and, furthermore, the extremely high insulation resistance of the material, which is a necessary accompaniment of its very low power factor, is a nuisance during wrapping because of static charges which accumulate on the surface and which sometimes require special measures for their removal.

Polytetrafluorethylene, known variously as p.t.f.e., Teflon and Fluon is an interesting example of a material suffering from the defects of its own specially favourable characteristics. Its power factor is very low, it is not attacked by any known solvent and it can be safely used up to 250° C; but (as aptly expressed by Dr. L. Hartshorn) the insulation engineer "stands wondering what on earth he can do with a material so intractable." It cannot be melted; when used as a wire covering it has to be prepared and applied in such a form that it exhibits plastic yield; for the same reason it cannot be moulded and must therefore be cold pressed as a powder and then sintered so that a porous structure results which is extraordinarily susceptible to discharges. As tape the material is slippery and cannot be tied and—as a direct consequence of its complete chemical inertness—it is impossible to use adhesives. The cost is high and at present its use is rather restricted.

Polychlortrifluorethylene (Kel-F) is somewhat similar to p.t.f.e., but it can be more readily moulded and as a wire covering it is less liable to plastic flow. The cost, however, is very high and the properties are not sufficiently attractive to create a large demand.

Terylene (polyethylene terephthalate) has received much notice recently. It has a high melting point (260° C) and can be made into fibres so that the woven material offers possibilities for use (in conjunction for instance with a silicone varnish) as a high-temperature-resistant material with good electrical properties and with better mechanical characteristics than glass fibre.

Rubbers

The shortage of natural rubber a few years ago stimulated chemists in various countries to produce an artificial substitute. Neoprene was developed in the United States and is perhaps the commonest synthetic rubber in Great Britain. Its insulation resistance is poor but it is more resistant than natural rubber to chemical attack by oils, oxygen and solvents. Similar developments have taken place in Germany.

Ceramics

There have been notable developments in the production of new ceramics which are of great theoretical interest and of considerable practical importance.

Ordinary porcelain made from quartz, felspar and clay has the advantages of imperviousness to moisture and of great heat resistance, combined with high electrical and mechanical strength, but unfortunately its power factor is not low enough to permit its use as a high-frequency dielectric. This defect, however, has been largely overcome in steatite, which consists mainly of soapstone—a hydrated magnesium silicate—with the addition of small quantities of clay and felspar.

Other developments to meet the demands of radio engineering have included the production of ceramics having a very small coefficient of expansion and a very small temperature coefficient of permittivity.

The titanate compounds form a special group. Pure titanium dioxide (rutile) has a permittivity of about 120, but the small additions of clay which are necessary for bonding purposes reduce this value in practice to about 85. Compounds containing barium and strontium titanate have permittivities up to 3 000 and barium-lead zirconate has a permittivity of 6 000. These latter are the so-called "ferro-electrics," and they have unique dielectric properties analogous to the magnetic properties of ferro-magnetic materials. They appear at first sight to be ideal for the manufacture of large capacitors and they have in fact been examined to that end. So far, however, their cost has prevented commercial development but the view has been expressed that materials of this kind offer possibilities of a substantial reduction in the size of capacitors.

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HOME EVENTS

LONDON

RADIO AND TELECOMMUNICATION SECTION

Ionospheric Radio Propagation

Radio-wave propagation does not usually attract large attendances at meetings of the Radio and Telecommunication Section unless there is some particular "box-office draw," such as the possibility of hearing some outstanding scientific personality, to overcome the seeming reluctance of the average telecommunication engineer to delve into the mysteries of this exceedingly fundamental realm. It was therefore a matter of considerable satisfaction that the two-session meeting held on the 31st October, 1955, was so well supported. This was undoubtedly due to the timely nature of the papers read and, in particular, to the lively interest currently displayed in the subject dealt with in the second part of the meeting.

The papers read during the afternoon session were *The Technique of Ionospheric Investigation using Ground Back-Scatter* by E. D. R. Shearman, *A Study of Ionospheric Propagation by Means of Ground Back-Scatter* by the same author, *An Experiment to Test the Reciprocal Radio Transmission Conditions over an Ionospheric Path of 740 km* by R. W. Meadows, and *An Experimental Test of Reciprocal Transmission over Two Long-Distance High-Frequency Radio Circuits* by F. J. M. Laver and H. Stanesby. After tea a paper on *V.H.F. Propagation by Ionospheric Scattering and its Application to Long-Distance Communication* by W. J. Bray, J. A. Saxton, R. W. White and G. W. Luscombe was read. Short reviews of these papers appear on pages 30, 32, 34 and 35.

Throughout both sessions, tribute was paid by several speakers to the pioneering work of T. L. Eckersley in the field of ionospheric scattering. He, more than any other worker, can fairly claim to have first directed attention to the scientific importance of this phenomenon, which was the subject of much of the day's discussion.

Mr. Shearman's two papers dealt with the subject of long-range back-scatter from the ground reflected at the ionosphere, as a means of investigating high-frequency propagation. Briefly, the nearest edge of the patch of long-range scatter signals seen on a radar-type display can be shown to come from the edge of the skip zone for the time, direction and frequency concerned. Both Mr. Shearman and several other speakers agreed that while T. L. Eckersley's early theory (that long-range scattering arises principally in the E region of the ionosphere) could no longer be held to be correct, the evidence now being that scattering by the ground (or sea) was predominant, it was true to say that the very earliest returns, given adequate transmitter power, probably did arise in the E layer.

In the discussion Mr. C. M. Minnis and Mr. W. R. Piggott referred to the discrepancies frequently occurring between observed maximum usable frequencies and those predicted from vertical incidence measurements. The tool provided by the methods described by Mr. Shearman could help in elucidating the cause of such discrepancies. An interesting phenomenon described by Mr. Shearman was the occasional occurrence of very long hops of 10 000 miles or more without any apparent intermediate reflection at the ground. Possible explanations were "M" type reflections involving the E and F layers or possibly the effect of appropriate tilts in the F layer at two widely separated points.

The two papers on reciprocity dealt with a subject which, as Dr. Smith-Rose pointed out later in the discussion, has engaged the engineer and scientist for over a century, without his being able to settle all aspects of the problem entirely to his satisfaction. Both Mr. Meadows and Mr. Laver demonstrated that so far as observable transmission loss was concerned occurrences of true non-reciprocity did occur. The unresolved question is whether these are all capable of explanation in terms of the known Faraday polarization-rotation effect. It cannot be said that either the papers themselves or the discussion that followed finally disposed of the matter. Mr. J. A. Smale, amongst other speakers, emphasized the reality of non-reciprocal conditions in practical radio-telegraph operation. He illustrated his remarks by quoting an extreme case in which traffic from Melbourne directed on London had to be relayed back to London from Barbados which lies beyond London on the same great circle. There seemed to be general agreement that noise levels at the receiving end of a circuit have a predominant effect so far as traffic capacity is concerned, especially when account is taken of the small threshold between workable and unworkable signals.

Dr. Smith-Rose took the authors of one of the papers to task for needlessly introducing a specialized network theory term (*image transfer constant*) into a paper on propagation in which the whole interest lay in the power loss over the path.

After tea the meeting reassembled to hear the paper on v.h.f. scattering at the ionosphere and its impact on long-range communication. The interest of the communication engineer has only recently been aroused in this subject despite the fact that the phenomenon of ionospheric scattering has been recognized for over a quarter of a century. Originally regarded as a matter of scientific curiosity and something in the nature of a nuisance to the practical engineer, ionospheric scattering at frequencies in the range 30 to 100 Mc/s (approximately) is now being seriously investigated as a possible means of long-range communication.

Dr. Saxton, who presented the paper, gave an exceed-

ingly interesting account of the work that has been carried out by the Post Office and the Department of Scientific and Industrial Research in collaboration with the Admiralty. In describing the phenomena observed, he gave the opinion of the authors that both turbulence in the ionosphere and ionization caused by meteor trails play a recognizable part. The paper was concluded by the playing of short recorded extracts illustrating the quality of telephonic communication over a link from the Shetlands to Jersey using both phase modulation and single-sideband systems. This demonstrated the practicability of such a long-distance telephonic link using scatter propagation.

Dr. Megaw opened the discussion and said that the credit for recognizing the possibility of exploiting long-range ionospheric-scatter propagation must be given to H. G. Booker. In his detailed comments Dr. Megaw took issue with the authors over their theoretical treatment of the relation between frequency and power scattered, explaining that the rapid falling off with increasing frequency could be explained simply in terms of the size of the irregularities causing scattering. This led the way to a lively and active discussion ranging from the purely scientific to severely practical aspects. Notable amongst the latter were the remarks of Dr. Smith-Rose who drew attention to the highly inefficient nature of this mode of communication. Thus, for example, very large powers and high-gain aerials are required to achieve somewhat marginal signal-to-noise levels, and, taken in conjunction with the restricted band of frequencies within which the phenomenon is important (a band, incidentally, already largely given over to television and other short-range services), this indicates that serious interference problems are likely to arise in any attempt to exploit the techniques on a wide scale.

If the discussion did not lead to any final conclusion as to the ultimate practical value of this novel means of long-distance communication it did at least ventilate many points of view from which in the course of time a balanced judgment will emerge.

Amongst the audience for the evening session were a number of American visitors, indicative of the very considerable interest being shown in this subject on the other side of the Atlantic.

In moving a vote of thanks to all the authors of the five papers read, the Chairman had the rather unusual experience of having to include himself amongst those whom he commended to the meeting! This he did excellently, with a most skilful omission of any reference to himself, however well deserved. W. R.

Full of Point

At the meeting on November 9th, with Mr. H. Stanesby in the chair, Dr. G. B. B. Chaplin presented a paper on *A Transistor Digital Fast Multiplier with Magnetostrictive Storage*, by R. E. Hayes, A. R. Owens and himself. A short review of the paper was published in the September, 1955, issue of the *Journal*. Much of the written paper is concerned with the logical design of this experimental device, which is difficult to convey orally, and Dr. Chaplin wisely concentrated on describing in some detail the ways in which point-type transistors were used. He stressed particularly the advantages which had been gained from using inductors in the base circuits of the transistors, and the encouraging reliability figures he quoted certainly seemed to be strong recommendation for this method.

A complete battery-operated magnetostrictive storage system was demonstrated, the pulses on the line being shown on an oscillograph and made audible by a loudspeaker, which emitted higher and higher notes as more pulses were injected into the line. It would seem that the compactness of transistor circuits makes possible more ambitious lecture demonstrations than would be attempted with valve circuits.

The discussion was opened by Mr. E. H. Cooke-Yarborough, who said that many people seemed surprisingly loath to use point-type transistors. He was not quite sure of the reason, for the paper showed that unreliability need not be a serious handicap. Was it, then, laziness in learning an entirely new circuit technique? He pointed out that many of the circuit functions described in the paper would be difficult to perform with even the more expensive junction transistors. Mr. T. R. Scott also spoke in favour of point-type transistors but said it was an unusual experience to follow two other speakers who had done likewise. He expressed the view that the point-type transistor would always be with us in some shape or form.

By this time it was clear that the discussion would revolve round the relative merits of point and junction transistors and Mr. B. W. Pollard spoke up in favour of junction transistors, saying that they were more stable and more reliable. Other speakers stressed the need for more statistics on the reliability of both types and by the time the authors were due to reply honours seemed about equal. In reply to one question, Dr. Chaplin said that in constructing the multiplier they had not needed to make any effort to reduce wiring capacitance and he showed a photograph of the multiplier which undoubtedly proved his point.

What were perhaps the two most telling considerations emerged from the discussion. One speaker said that, whatever one might say about the merits of different types of transistor for computers, the final decision would be made by the man in the street, for manufacturers would produce transistors primarily for radio and television sets. Dr. Chaplin emphasized that the virtues of fast point transistors were present facts, whereas those of fast junction transistors were mainly future hopes. E. H. C.-Y.

SUPPLY SECTION

Flat Pressure Cable

A discussion on very-high-voltage cables, like tariffs, is invariably lively and attracts a good audience. Tradition was well maintained at a meeting on the 23rd November,

1955, when J. S. Møllerhøj, A. M. Morgan and C. T. W. Sutton presented their paper on *Flat Pressure Cable* before 238 members and visitors. A short review appears on page 37.

Mr. Sutton, in introducing his co-author from Denmark, modestly described the cable as "a variation on an original theme," and Mr. Møllerhøj then gave a short outline of the paper. He emphasized the self-compensating features which eliminated the need for the accessories associated with conventional oil-filled cable. Since 1941 about 120 miles of 3-core flat cable had been installed, mostly in Denmark or in Danish waters, including the 132 kV circuit between Denmark and Sweden laid in 1950–51—all with trouble-free records. The cable can be made in relatively long lengths, which makes it particularly suitable for submarine installations. Laying of the cable at sea has been carried out by the floating drum method, and Mr. Møllerhøj illustrated this by an interesting film. Unfortunately the film missed a good deal of the work, as bad weather had interfered with the photography.

The discussion was opened by Mr. F. J. Lane, with a critical assessment of the cable for submarine purposes. He thought the 3-core construction an advantage from the point of view of space occupied on the sea bed; on the other hand, any damage is bound to affect all three phases of the circuit, and the making of three-phase joints at sea would be a formidable task. He thought a large number of such joints would be needed for a cross-channel connection. The floating drum method of laying, which incidentally is the only method available for laying this cable in really long lengths, could be very hazardous in the open waters of the English Channel. Mr. Lane questioned the selection of aluminium alloy as an armouring material in preference to steel on the score of erosion in sea water.

Monsieur R. Tellier, in a lucid contribution delivered in excellent English, gave some account of the extensive investigations carried out by Électricité de France. He emphasized the relationships between loading cycles and oil-pressure variations within the cable, and wondered if the overload rating should be determined by manometer or ammeter. Following on the same point, Dr. A. N. Arman questioned pressure conditions in the cable if laid on land on gradients.

Mr. D. B. Irving found interest in what was left out of the paper, as well as what was included. He, like Mr. C. C. Barnes, Mr. J. Banks, and Mr. G. S. Edwards, asked for more information and data in support of the test results claimed. Mr. C. H. Gosling asked if the flat cable could be pulled through ducts, and thought that if used in London, transposition of phases would be essential. Mr. E. E. Hutchings touched on the same point, with a reference to unbalanced impedances and thermal conditions due to the unsymmetrical arrangement of cores.

The discussion then veered towards economic comparisons, and a point was well taken by the next speaker, Mr. D. T. Hollingsworth, who suggested that flat pressure cable would cost 3% to 4% more to manufacture than other types of cable of equivalent rating. His remark that this would absorb the whole of the manufacturers' profit caused some hilarity amongst the audience. On the other hand, Mr. G. S. Buckingham thought the possibility of using the cable in very long lengths, with consequent reductions in the "astronomical" cost of joints, should appeal to the mains engineer.

Mr. Morgan replied to the body of the discussion, quietly and competently, and Mr. Møllerhøj rounded off the discussion with a few additional comments.

The Chairman moved the customary vote of thanks in graceful terms, so ending a very successful meeting in which the natural interest of the subject was enhanced by the presence of Mr. T. Michielsen of Holland and Mr. F. Sykes from Australia, as well as the two visitors from oversea who had taken an active part. D. P. S.

UTILIZATION SECTION

The Engineer in the User Industries

At the first meeting of the session on the 13th October, 1955, the new Chairman, Mr. D. B. Hogg, delivered his Address, which dealt with the opportunity and interest for electrical engineers in "user industries," that is, in industries other than electrical manufacturing, supply or contracting. The meeting was honoured by the presence of the President.

Mr. Hogg considered that such appointments outside the electrical industry enable their holders to become "engineers" in the fullest sense instead of "electrical engineers," because the problems to be dealt with are so wide that these men are encouraged to explore other engineering and scientific fields. He maintained that there still exists a considerable amount of mystique in industry in Britain, and the well-educated and intelligent engineer could do a service to industry by being able to sort the "wheat of inherited skills and know-how from the chaff of dead custom and inertia." Also, he was of the opinion that it was highly probable that the number of different duties which an electrical engineer in the user industries has to undertake will not be equalled elsewhere.

Mr. Hogg, in his concluding remarks, referred to the present practice of some of the larger firms in industry of making special efforts to recruit university graduates for training in their own works. In his opinion, such men's fundamental knowledge and training to think carries them more readily into the higher-paid posts and at an earlier age than is often attained in other circumstances. Apart from the rewards of experience and interest, the financial opportunities are at least as good as, and often better than, those in electrical manufacturing and supply.

A vote of thanks was accorded to the Chairman after his Address and the meeting terminated with a vote of thanks to the retiring Chairman, Mr. J. I. Bernard, for the excellent work he had done for the Section during his term of office and the presentation to him of a certificate to commemorate the occasion.

Braking Methods

At the meeting on the 17th November, 1955, two papers were read. The first of these was entitled *The Dynamic Braking of Induction Motors* by D. Harrison, a short review of which appears on page 38. The author showed by means of a simple graphical construction that it was possible to predict the dynamic braking torques of slip-ring and squirrel-cage induction motors and indicated that the test results confirmed the accuracy of this method. He also described a method of calculating the total deceleration time of an induction motor under dynamic braking conditions. Dynamic braking of this nature, which consists of exciting the stator windings by direct current, is widely used for mine winders and for the quick retardation of machines of high inertia.

The other paper, given by C. Cuthbert and D. A. Picken, was *Timing the Operation of Control Systems associated with Rotating Equipment*. A short review is on page 33. This dealt with the problem of ascertaining the exact time of operation of a contactor or braking device in a sequence, and described simple apparatus, capable of measuring such times to better than one-thousandth of a second, which has been developed in connection with various methods for braking two-roll mills in the rubber industry. This technique employed the attachment of electro-sensitive paper to the surface of one roll, on which the traces of a stylus, supplied by alternating current, determined the exact speed of the roll, additional styluses being applied to the paper to indicate the actuation of the various braking devices.

It was somewhat noticeable in the ensuing discussion that the contributions fell into two distinct categories—those which dealt with theory and design, and those concerned with practical application. Some of the former were certainly to the point and quite hard-hitting, such phrases being used as "needs a lot of swallowing," "equivalent circuits have become the rage," "the influence of Dr. Hopkinson is too great," etc. An interesting point was made by one speaker who suggested that the stop-and-start action of the brakes observed by Mr. Cuthbert and Mr. Picken seemed similar to "brake fade" in motor cars, where, with strong brake application, resinous material was evaporated and deposited on the brake drum, with consequent reduction of the coefficient of friction. The solution in such cases was to heat the brake shoes before their installation to such a temperature as to drive off all the resinous material. Another contributor pointed out that as two-roll mills in the rubber industry usually had to work in filthy surroundings, which could seriously affect the efficiency of electro-mechanical brakes, he now preferred the "electrical plugging" brake, in which the stator current is reversed and the full starting resistance is put back in the rotor circuit, with everything in an airtight, dustproof case. In reply to this Mr. D. A. Picken said that the drawback of "electrical plugging" was that, if the contactors welded in the drive position or failed to make in the reverse position, the machine was left without a brake, which could also occur if the fuses blew or the stop button was operated. R. H. R.

GLASGOW

SCOTTISH CENTRE

The annual dinner-dance of the Scottish Centre was held in Glasgow on November 15th, when a record number of members and guests, including the President of The Institution and many student members, assembled under the Chairmanship of Dr. E. Wilkinson. The toast to The Institution was proposed by Mr. Melville Dinwiddie, Scottish Controller of the British Broadcasting Corporation. He referred to the need of the Corporation for men of the highest qualifications and greatest moral integrity, and acknowledged the great help given, in this and in other respects, by The Institution. In his reply the President also spoke of the need for men, not only with high academic distinction, but with the requisite mental qualities to plan and direct industry. The toast of "The Guests" was proposed by Mr. J. A. Aked, Chairman of the South-West Scotland Sub-Centre in a very amusing speech, and replied to by Mr. E. L. Denny, Chairman of the Scottish Branch of The Institution of Mechanical Engineers, who told some humorous tales about Clyde riveters. The health of the Chairman was proposed by Professor F. M. Bruce, Senior Vice-Chairman. In the course of the evening Mrs. Wilkinson charmingly presented the Hutcheson–Winning Golf Trophy to Dr. J. Jamieson, who has now won the trophy three times—even so he is not to be allowed to keep it. Mr. Aked, in his speech, referred to a new unit of time—the "de Villiers"—and by strict rationing of the speeches in terms of this unit it was possible to have adequate time for a most enjoyable spell of dancing.

Highland Water Power

The Glasgow meeting of the 23rd November was tinged with sadness as it was the first reading of the paper on *Highland Water Power* by the late Mr. T. Lawrie, whose death has so recently been mourned. Before a large audience, which included members of The Institutions of Civil and of Mechanical Engineers, the paper was presented by Mr. A. A. Fulton, General Manager of the North of Scotland Hydro-Electric Board and Mr. C. L. C. Allan, Chief Mechanical and Electrical Engineer. After briefly tracing the history of Highland water power, the paper describes the main body of the work, which is now about half completed; the plant installed is about 634 MW and it is expected to generate about $1\,620 \times 10^6$ kWh in the season 1955–56. Among items of special technical interest mentioned in the paper are the largest single generating-unit in the Highlands (40 MW in the Shira scheme), the highest head (1 362 ft in the Lawers scheme), a 20 MW 250 r.p.m. 175 ft-head Kaplan turbine, the 132 kV line over the 2 507 ft Corrieairack Pass, a proposed 275 kV line from Beauly to Kintore in Aberdeenshire, the Allt-na-Lairige pre-stressed concrete dam which has a height of 73 ft and a length of 1 375 ft, and the rate of tunnelling which, for a 10 ft tunnel, has reached 444 ft per week. The great importance of salmon

fishing has necessitated the construction of various types of fish pass to enable the fish to negotiate the dams and the provision of new spawning grounds to replace those submerged by the reservoirs. Two fish hatcheries have been built and an electronic fish-counting device installed at one location; this not only counts the number of fish passing but distinguishes between those ascending and descending, and between those above and below 6 lb in weight. Laboratory experiments have shown that smelts can successfully withstand the pressure due to 200 ft head of water, and at three sites the smelts are permitted to pass through the turbines (Morar, 17 ft head, Torr Achilty, 45 ft, and Pitlochry, 55 ft). Amenity has received great attention in all installations and the works in Glen Affric have been specially praised by the Council for the Preservation of Rural Scotland. Power stations and staff dwellings are built of local stone which has an appearance appropriate to the landscape and also maintains a valuable local industry. Not only is the development of Highland water power bringing electricity and other amenities to the Highlands, but it is also bringing work to the industrial Lowlands in manufacturing much of the hydraulic, electrical and other plant required. E. O. T.

OXFORD

DISTRICT MEETING

The second meeting of the session was held at the district office of the Southern Electricity Board on the 9th November, 1955, when over 50 people comprising members and their friends gathered to hear Dr. R. H. Golde read a paper on *Lightning Surges on Electrical Supply Systems.*

After discussing the development and forms of lightning discharges, Dr. Golde described the mechanism of the discharge to a transmission system. He gave information about the magnitude and waveshapes of lightning surges, and about the effect of surges on lengths of cable in series with overhead lines. He then described the protective system with particular reference to overrunning earth wires. The paper was illustrated by excellent lantern slides and diagrams and the discussion which followed showed a keen interest in this important subject.

A vote of thanks to the speaker was proposed by Mr. W. H. Lee, who voiced the unanimous opinion that the evening was a great success. V. B.

STAFFORDSHIRE

NORTH STAFFORDSHIRE SUB-CENTRE

Chairman's Address

Mr. J. M. Ferguson took the chair for the first part of the opening meeting held at Stoke on the 7th October, 1955, and formally welcomed Mr. A. B. J. Reece and Mr. J. Richards as Corporate Members. He then introduced Mr. H. S. Davidson, the newly elected Chairman of the South Midland Centre, who congratulated the Sub-Centre on its continued progress and increase in membership. He considered that although there is a great need to increase the number of scientists and fully qualified engineers in industry, this should not be achieved at the expense of quality and the high standards set by The Institution must be maintained.

Mr. Davidson referred to the Institution Summer Meeting, which will be held in the South Midland Centre from the 25th to the 29th June, 1956, and asked for the full support of local members, especially as the President, Sir George Nelson, is a member of the Centre. An interesting and attractive programme is being arranged.

The Chairman invited Dr. E. R. Patrick to deliver his Address *Engineering Manpower.* Dr. Patrick explained that while progress depended largely on science and engineering, the source of suitable manpower was limited. It seemed unlikely that the proportion of boys entering engineering could be increased to any great extent, and the problem became one of developing the available manpower to the highest possible level.

After the customary vote of thanks to the speaker proposed by Mr. H. A. P. Caddell, the Chairman thanked the Committee for their keen support and enthusiasm during the past year and particularly mentioned the Honorary Secretaries, Mr. W. G. Friggens, who had now left the district, Mr. J. G. Wood, who had carried the duties temporarily, and Mr. E. Bolton, the present Secretary. He then formally invited Dr. Patrick to take the chair.

Dr. Patrick thanked the members for the honour they had conferred in electing him and hoped that he might be able to fulfil at least a small part of their expectations. He thanked Mr. Ferguson for his service during the past year and said he had occupied the chair with dignity and enthusiasm; his experience as a member of the Council of The Institution had been of great value to the Sub-Centre and it was hoped that he would continue to give his full support and interest. Mr. Davidson presented copies of *The History of The Institution* to Mr. Ferguson and Mr. Friggens in recognition of their services.

The meeting concluded with buffet refreshments and a conversazione which provided an excellent opportunity for members to get together informally.

Circuit-Breakers

At the meeting at Stafford on the 28th October, the Chairman, Dr. E. R. Patrick, formally welcomed Mr. W. J. Joyce, Mr. C. L. Penman and Mr. T. J. Rowlands as Corporate Members and introduced Mr. R. W. Fenn, who read the companion papers *A New Testing Station for High-Power Circuit-Breakers* by J. Christie, H. Leyburn and R. W. Fenn, and *Proving the Performance of Circuit-Breakers, with Particular Reference to Those of Large Breaking Capacity* by J. Christie, H. Leyburn and

J. F. Bird. These papers brought up a number of controversial questions and led to an active discussion opened by Mr. J. A. Prescott and Mr. E. A. Madenski and ably dealt with by Mr. Fenn. Mr. J. L. Hewitt, in proposing a vote of thanks to the lecturer, said that the development of switchgear to deal with the highest voltages and breaking capacities had been rapid, and these papers setting out the present position served a very useful purpose. Their value had been enhanced by the lively discussion they had evoked. L. G.

NEWS *from Abroad*

IRAQ AND PERSIAN GULF JOINT OVERSEA GROUP

BAGHDAD

The Iraq and Persian Gulf Joint Oversea Group held its first meeting of the 1955–56 Session in Baghdad on October 20th, when Mr. Niazi Fetto, the new Chairman, gave his Presidential Address. This was followed by a talk on *The Use of Films in Training* by Mrs. B. Shearman, who used seven documentary films to illustrate her talk, among them being one training film on industrial safety made in colloquial Arabic for local use.

On the morning of October 21st, members, with their wives and guests, were taken on a conducted tour of the new South Gate Bridge, Baghdad, at present under construction. The eastern approach bridges Baghdad's main shopping street, and the first span-and-a-half is now built out over the River Tigris. A fine view of the remaining works was obtained from the dizzy edge of the projecting steelwork. Crossing by launch to the west bank, members inspected the western approach ramp, then walked out along the contractor's footbridge to see completed piers and the last caisson from above.

Returning to the launches, the members were taken back to the east bank, and the meeting was brought to a close with a buffet lunch in the garden of the Mansur Club.

BASRAH

Oil Films

The November meeting of the Group was held in Basrah before a good attendance of members and their wives, from Baghdad, Abadan and Kuwait. In the absence of Mr. N. Fetto, the Chairman of the Group, the meeting was presided over by Mr. J. M. Morris, O.B.E. He welcomed the appearance of the ladies at the meeting and hoped that their example would be followed on future occasions.

Mr. C. E. Skerrey gave a most interesting talk called *Telecommunications of a Large Oil Company*, a feature of which was the showing of two films. The first, entitled *Oil of Iraq*, was in colour and gave a vivid impression of the tremendous developments engendered in a country by the discovery of oil. The second provided a dash of excitement unusual at an academic meeting, showing as it did the progress of an oil-well fire from start to finish. The film was made during an actual fire in a neighbouring field, when the blaze was extinguished only after 15 days of intensive fire-fighting.

An excellent tea was served before the meeting, and a cocktail party afterwards concluded the first day's programme. On the following day the party toured the Zubair oilfield and visited the new power station..

The thanks of the Group are due to the management of the Basrah Petroleum Co., who kindly permitted the use of the Barjisia Club for the meeting and arranged the tour of the oilfields. B. S.

SOUTH AUSTRALIA

Growth of Membership in South Australia

In recent years the growth in the number of members resident in the State of South Australia has been spectacular. The total (all grades) in 1939 was 28, in 1948 it had grown to 51 and to-day it hovers at about 110. By comparison the growth in the population of the city of Adelaide for the period from 1947 to 1954 was 26%.

Reasons for this increase in membership are not hard to find. In 1946 Professor E. O. Willoughby was appointed to the newly created Chair of Electrical Engineering at the University of Adelaide and over the intervening years a number of his students have become members. Soon afterwards the Long Range Weapons Establishment was started at Salisbury, near Adelaide, and as its organization expanded many electrical engineers and scientists from Government and private concerns in England found employment there. Many new industries have been established in the suburbs of Adelaide since the war ended, and, with the expansion of existing factories, there has been a rapid growth in demand for electric power. In fact the Electricity Trust of South Australia and the Weapons Research Establishment (as it is now called) each account for about 20% of our membership.

As the majority of members live in or near Adelaide, the South Australia Oversea Committee try to arrange about nine monthly technical meetings in Adelaide each year. Whenever possible a visitor from oversea or from another State is invited to speak, but such visitors are invariably extremely busy, and the number of them is comparatively small. For the other meetings the Committee arrange a programme of lectures by local speakers on subjects ranging from substation practice to the peculiarities of the ionosphere.

Television "Down Under"

At a recent meeting Mr. R. B. Mair of the Australian Broadcasting Control Board gave an account of the frequency allocations and technical standards for the Australian television service which will begin operating in Melbourne and Sydney late in 1956. A 625-line 25-frame system (C.C.I.R. European standard) with negative modulation has been chosen, and ten channels have been allocated in the band 49–216 Mc/s. One national and two commercial stations will be licensed in each capital city. Channels in the u.h.f. region from 500–855 Mc/s are also being reserved, but it is not intended to use these at first because it is felt that techniques for transmission and reception are not so well advanced as at lower frequencies. Television will soon arrive and its possible effects on national life are being as hotly debated in Australia as they have been in other parts of the world.

The Secretary of the South Australia Oversea Committee, Mr. H. A. Prime, has recently resigned in his third year of office. He will return to England in November to take an appointment in Loughborough, and his energetic personality will be missed by all members in this State. The Committee has appointed Mr. J. W. Crompton to fill the vacancy. J. W. C.

OVERSEA ATTENDANCE REGISTER

During the period 1st November to 30th November, 1955, the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

ANDREWS, G. J. (Buenos Aires).
BASIL, D. A. (Calcutta).
GREAVES, S. (Aden).
HARGREAVE, E. (Kingstown, St. Vincent, B.W.I).
HICKS, A. L., Lt.-Col., R.E., O.B.E., B.A. (H.Q., B.C.F.K., B.A.O.P.5).
McDONALD, J. R., B.SC.(ENG.) (Kingston, Jamaica).
MALEKSEERAT, H. (Masjid-i-Sulaiman, Abadan, Iran).
PRIME, H. A., M.SC., B.SC. (Adelaide)
TRAFFORD, W., M.B.E. (Singapore).
TWITCHETT, A. J. (Tanga, Tanganyika).

Convention on Digital Computer Techniques

9th to 14th April, 1956

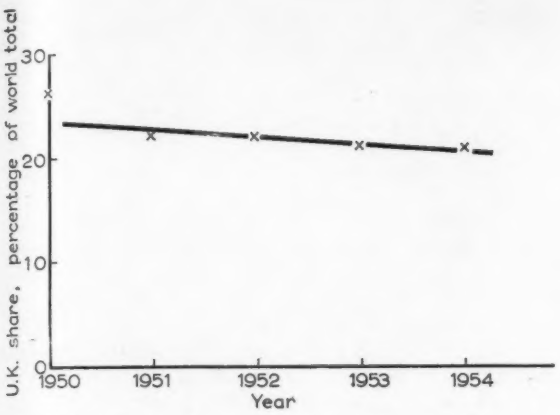
As previously announced, the Committees of the Measurement and Control and the Radio and Telecommunication Sections of The Institution, in collaboration with the D.S.I.R. Committee on High Speed Calculating Machines, are arranging a Convention on Digital Computer Techniques to be held at The Institution from the 9th to 12th April, 1956, followed by visits to digital computer installations on the 13th and 14th April.

Announcements concerning the submission of papers for the Convention appeared in the June and November, 1955, issues of the *Journal*. The provisional plan for the Convention is given in the table which is printed alongside this notice; the General Sessions and the Specialist Sessions will be held simultaneously. As many as possible of the papers to be presented will be available in advance on payment of a nominal fee, and the complete proceedings of the Convention will be published subsequently in a supplement to Part B of the *Proceedings of The Institution*.

The Convention is open to members and non-members of The Institution (the latter being required to pay a registration fee of £1), and those who wish to attend are requested to apply to the Secretary of The Institution for a registration form. This will be sent to them during February, together with complete details of the programme.

Tickets will be necessary for the sessions and technical visits, and application for these, for copies of the papers, and for the supplement to Part B of the *Proceedings*, should be made on the registration form.

GENERAL SESSIONS	SPECIALIST SESSIONS
Monday, 9th April	
Opening session and introductory lectures	
Tuesday, 10th April	
Engineering and scientific applications of digital computers	Numerical analysis
Business applications of digital computers	Logical design
The application of digital computers in industrial control	
Wednesday, 11th April	
Construction and performance	Rapid access storage including the use of magnetic cores for storage and switching
(i) Large machines (ii) Small machines (iii) Experimental machines	Magnetic tape (input, output and auxiliary storage)
Thursday, 12th April	
The transistor (i) Present state of development and future prospects (ii) As a computing element	The transistor
Input and output including analogue-digital conversion	
The computer in a non-arithmetic role	
Friday, 13th, and Saturday, 14th April	
Visits to digital computer installations	



The United Kingdom's share of the world market for manufactured goods is decreasing

The Long-Term Industrial Outlook for Britain

G. L. E. Metz, M.I.Mech.E., Member

At an Ordinary Meeting of The Institution on the 3rd March, 1955, the author of this article read a paper entitled "The Electrical Engineering Industry in the Post-War Economy—II," which was republished in the December issue of the Proceedings, Part B. In it he surveyed some of the main achievements of industry as a whole since the Second World War, and the major problems facing it in 1955, with special regard to those of the electrical manufacturing industry. Mr. Metz emphasized the requirements for greater exports and productivity, and in this brief article he touches on them again, while surveying some industrial features that will shape the economic future of Britain. Successive crises and upsets in the balance of Britain's external trade since 1945 have exemplified that this future is not nearly so assured as the spread of the five-day week and the lack of drive for foreign markets by some industries might indicate. The electrical manufacturing industry is not guilty in the second respect, and in its roles as Britain's second-largest exporter, and, together with the supply industry, as a paramount source of industrial vitality, it is in the thick of the fight to stabilize Britain's economy. Both strategical and tactical success in this fight depends much on members of The Institution.

HUMAN activities have this in common—they tend to continue in the future the things that have been done in the past. As all industry derives from the application of human effort it follows that any attempt to look into the industrial future of Britain must start with a consideration of the past. It is of course impossible to deal with every industry within the compass of a brief review such as this because there are so many. But all these industries and their manufactures derive from a comparatively small number of raw materials which are provided by nature and which originate in the earth, the sea or the air. The application of human effort to this small group of starting materials results in the vast range of secondary materials and finished goods made in this and other countries and on which their economy and standard of living have come to depend.

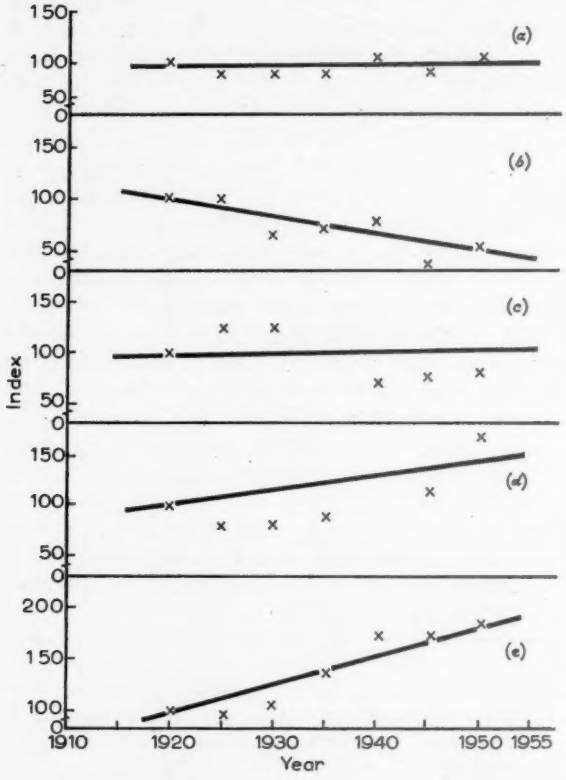
Trends in Demand

The production or consumption of some of these basic materials in the United Kingdom during the last few years is shown in Fig. 1. The annual increase in the consumption of many of them, e.g. coal, cotton, timber, sulphur (in the form of sulphuric acid) and salt, which form the starting-point for a vast range of other materials and finished goods, has not been large, and for some materials, e.g. coal, production is actually less to-day than it was in 1913. The production of other equally important starting materials such as pig iron, steel, copper, etc., has also increased at only about 3–4% annually. The number and variety of some finished goods made from these raw materials have of course increased much faster, e.g. motor vehicles, electrical goods, and hosiery, and this is also true of electrical energy. However, these are exceptions and the total gross domestic product of all industries taken together at 1948 prices (Fig. 2) has advanced little more than 2½% annually. So it seems that production and consumption of all commodities in this country, which as a result of monthly statistics have come to be regarded as varying in an exciting and erratic manner, in fact reduce over a long term to a slow and unexciting growth of little more than 3% annually. When taken over a period of fifty or sixty years, the effects of wars, booms, famines and slumps tend to appear as ripples on an otherwise smooth curve.

Turning now to the world at large, we find (Fig. 3) that the growth of world production and international trade (for all commodities taken together) has followed a course very similar to the growth of production in the United Kingdom. Indeed industrial activity in this country has advanced arm in arm with world demand at an almost identical rate. In other words, the spending power of the world and of Britain seems to have advanced during the last two or three decades at a steady but rather low rate which shows no signs of increasing materially in the near future. It follows that such opportunities as exist for increasing industrial activity in Britain above its present rate consist not so much in seeking to increase the size of the world market as in taking a larger share of that market. To do this it would be necessary to produce more goods in the United Kingdom, to increase our efficiency of production

relative to that in competing countries so that our prices are lower, and to produce goods that are new, attractive and unobtainable elsewhere.

A sober examination of the evidence available brings to light some disconcerting factors that may surprise some of those associated with the electrical manufacturing industry, which has been so outstandingly successful during these last few years. First, although British exports



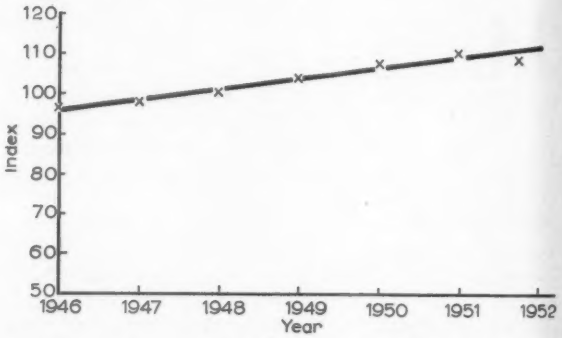
1 *Indices of United Kingdom production and consumption of certain basic raw materials (1920 ≡ 100)*

(*a*) Coal (U.K. consumption).
(*b*) Cotton yarn singles (U.K. production).
(*c*) Soft wood (U.K. consumption).
(*d*) Sulphuric acid (U.K. production).
(*e*) Salt (U.K. production).

have recently increased with expanding world trade, they are not increasing so quickly as German and Japanese exports and as a result Britain's share of world trade has been falling (see the diagram at the head of the article). Secondly, for some time productivity (averaged over all industries) in the United Kingdom has been lower than that in the United States and relative to other countries with which we have to compete has not been spectacular. Thirdly, the United Kingdom has for some time had full employment, so that any increase in production would have to come from a more efficient use of human effort and plant and by using machines for some of the operations at present done by hand. In short, people would have to work harder, more effectively and perhaps longer, and would have to develop an enthusiasm for the effective use of labour-saving devices.

From statistics of this kind, taken over a fairly long period of time, it becomes possible to see the general trend of demand and production over the last few years and to foresee and plan for the future on the general assumption that industry will continue to follow the path it has been following in the past. It would be rash to expand the productive capacity of most industries faster than the steady but slow growth in world and national demands. But this is not true of certain ones, such as the electrical supply and manufacturing, and the chemical, industries; these are rightly running ahead of the field to gain their proper economic place in the pattern of industrial and domestic activities.

The notion of a slow steady rise in world demand and



2 *Index of gross domestic product valued at 1948 market prices (1948 ≡ 100)*

purchasing power unaffected over a long period by boom and slump may be a useful guide to long-term planning, but it is of little help to those responsible for keeping factories fully employed from year to year. It is cold comfort in a period of slump extending over one or two years, as in the early nineteen-thirties, to point out that all the trials and tribulations which at the time loom so large will, over a period of twenty or thirty years, seem trivial and unimportant; the unpredictable changes in demand from month to month are, of course, immensely important to industrialists.

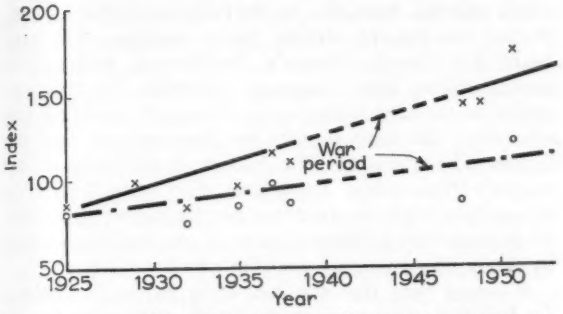
Nevertheless the long-term industrial outlook of Britain is linked with the slow but steady increase in world demand, and it is important to bear in mind that this absorbs the whole spending power of the world community.

It is only by putting more skill and effort into her productive activity that Britain can increase her share of this purchasing power.

Britain's Position in World Developments

Seventy years ago Britain bestrode the world like a colossus—she was the leading industrial nation, with a vast empire to take her manufactured goods and a productivity and a standard of living superior to those of any other country. To-day, great parts of that Empire have attained Dominion status with important and thriving industries of their own; our output per man-year and our standard of living have fallen from their leading position in regard to other countries, and, as already stated, our share of world trade has also been falling in recent years.

Instead of the world becoming a friendlier place in which neighbours freely exchange their surpluses, we see



3 *Movement of world production and international trade for all commodities (1929 ≡ 100)*

———— World production.
—·—·— Volume of international trade.

on many sides the desire to preserve national, social and economic autonomies and to close the doors on the exchange of ideas and of merchandise. This makes it particularly important to bear in mind Britain's position relative to that of other countries, to take account of the rapid increase in production by our competitors and to recognize the difficulty of acting as the workshop of a world in which each country wants to have a workshop of its own. This is bound to make problems for us because Britain has few natural resources in the form of raw materials, and her prosperity depends upon her ability to convert imported raw materials into finished goods that other nations want.

The effect of this trend has been made much more severe by the two world wars. The world looks for its leaders among the strong, and Britain, having suffered grievous injuries in two world wars in which she sacrificed much of the treasure accumulated during the lush period of the nineteenth century, is still economically weak. If she is to remain great, at the centre of a great Commonwealth and Empire, she must rebuild her economic strength and accumulate afresh the capital reserves necessary to develop her brilliant ideas from pipe dreams into realities. For a manufacturing nation this means that productivity has to catch up and overtake that in competing countries; for Britain in particular it means that her production, her exports, her share of world trade, must be increased. This task has a special significance for the electrical industries because they constitute one of the keys to increased productivity. They provide the additional power which, owing to full employment, is not available in the form of human effort. On them depends to a large extent whether Britain goes forward or back.

The Electrical Industries' Part in the Industrial Development of Britain

From the beginning of the Second World War the demand for electricity and electrical devices in Britain has increased spectacularly year by year and far exceeded the capacity available for production. This prosperity has been due more to a variety of external causes than our own prescience. These favourable external influences are passing, and the day is fast approaching when the fight for markets will be as intense as it was before 1938. So there are selfish as well as national reasons why electrical engineers should consider where their industry is heading and what progress it is making.

The necessity of making better use of the resources of plant and human effort at our disposal and of doing more hand operations by machines has brought the electrical supply and manufacturing industries from a minor part on the stage of national affairs to that of one of the leading characters. The old, comfortable notion, of a rigid departmentalized society where the individual gets on with his job and does not bother too much about what is happening in other sectors of industry, is quickly passing. A new balance has to be worked out between the work to be done by machines and that to be done by hand, and this time it will have to take account of psychological factors and to provide work for those displaced by machines. The future will depend to a large extent upon the success attained in reaching this new balance and the engineer has a very important contribution to make towards framing it. The author's paper referred to above points out that advances in technical knowledge have removed nearly all the barriers to efficient production and asks why it is that in many industries production units that are models of efficiency remain side by side with others which are reminiscent of the nineteenth century. It dismisses the popular view that if the capital equipment and power at the disposal of each worker in Britain could be increased to that in the United States, productivity here would rise as quickly as it does there. The answer is not so simple as that because the advantages of more power and more machines, the application of time study, the streamlining of processes, the use of incentives, etc., have been known and practised here for many years. None of these aids is of any avail without the will to use them effectively. It is these circumstances which make psychological and human factors of such vital importance to-day. Nobody believes to-day that production can be raised merely by raising wages, for it is recognized that men do not work merely for money, and one is reminded that all the really great movements

in history have arisen, not from man reaching after wealth, but from his inward desire to be a partner in a worthy enterprise of high endeavour. Col. B. H. Leeson, in an admirable contribution to the discussion of the paper which ranged searchingly over the whole subject, put his finger on the crux of the problem, so far as the engineer is concerned, when he pointed out that the electrical industry can contribute to the national well-being only as much as society will allow it to do. The problem is to convince industrialists of our ability to help them increase production and exports and to persuade them to use the aids to production that we engineers design and make. We must keep in mind that it is now possible to control factories automatically without the use of operating labour and to replace the large clerical staffs at present used for such services as the calculation of wages and of P.A.Y.E. by electrical computing machines. There is no difficulty in designing and constructing the machines and control devices for this purpose but what is difficult is to decide how these new-found possibilities can best be applied and how the displaced labour can be usefully employed.

The transfer of work from men to machines is not a new development, it has—for reasons not always fully appreciated—been going on quietly for many years. This transfer has taken place not only with the object of increasing production but also because of the growing disinclination of society to undertake heavy and unpleasant tasks and because of the dearth of skilled craftsmen who can use their hands. It has been accelerated by full employment and by the fact that the output of a machine can be predetermined, whereas the output of a man depends upon his attitude of mind and will to work. The future economic well-being and happiness of society therefore depend greatly upon the wisdom with which the engineer exercises and applies the new possibilities his ingenuity has made possible. This calls for considerations that go far beyond the realms of engineering science and practice.

The Institution has reacted to these new influences and has already extended its frontiers to include the consideration of problems that until recently would have been regarded as well outside its sphere of responsibility and interest. During the 1954–55 session, besides the discussion of the author's paper, members were able to hear a lecture by Lord Citrine on "Human Relations in Industry" which was remarkable for its sincerity and wisdom (see October *Journal*, page 622), and the stimulating observations of Sir Harold Hartley in his lecture on "The Engineer's Contribution to the Conservation of Natural Resources" (see September *Journal*, page 553), which referred, *inter alia*, to the fully automatic factory. During the present session, many members will have heard Sir George Nelson's Presidential Address, in which, among other important problems, he lays emphasis on the need to find more technically qualified men who have the natural gifts for management and the highest administration. The Address is published in this month's *Proceedings*. These four discourses, which, on the surface, have no apparent connection were, in fact, all dealing with different aspects of one problem created by the rapidly changing world in which we live.

It seems then that the long-term industrial outlook for Britain is very much in the hands of the members of The Institution, for on the results of their work largely depends whether Britain goes forward or back. But it is a problem that cannot be solved merely by doing more assiduously the things we are doing now. The situation calls for a reassessment of the things we have come to regard as worth while and worth working for, and fresh thought on the ways in which we can make our contribution more effective.

A Discussion Meeting

TRANSFORMER LIMITS

A Supply Section discussion on the thermal rating of transformers, which was opened by Mr. R. A. Grierson, took place at Savoy Place on the 16th November, 1955.

Opening Dissertation

MR. GRIERSON said that the capitalized life of transformers is usually assumed to be about 25 years, but the actual life of an individual transformer is related to the temperatures at which it operates, which in turn depend on the loads imposed and the temperature of the cooling medium. Temperature-rise limits for oil and windings are laid down in B.S. 171: 1936, but limited guidance is given in that specification about loading—an aspect which will undoubtedly be rectified in the next edition. The present basis of loading would appear to give a very long life, and it would be interesting to have users' comments on this aspect, as it leads to consideration whether the loading practice has been too pessimistic in its assumptions regarding deterioration over the years.

The qualifying factors are the temperature/deterioration relationship for solid insulation and transformer oil, and the determination of two temperatures—the basic temperature for normal life-expectancy calculations, and the upper limit of temperature under conditions of extreme load but excluding short-circuit.

Investigators have obtained data on rates of deterioration, defining them in mathematical form, and confirmatory tests have been carried out on complete

transformers. Of necessity such tests have employed some degree of acceleration which may detract from their accuracy. Furthermore, being obtained under laboratory conditions, such data are not strictly comparable with those for service conditions. From the experiments two theories have emerged, one that ageing can be assessed on the tensile strength of paper and the other that it should be assessed on the rate of chemical deterioration. The findings differ in that they indicate different rates of deterioration for given temperatures, and owing to their logarithmic nature, appreciable differences are apparent at elevated temperatures.

Transformer-oil tests indicate that deterioration in non-inhibited oils starts to become serious above 75° C. Conditions are improved if a nitrogen seal is employed or the temperature of the oil in contact with the atmosphere is reduced by means of a conservator.

The permissible sustained temperature for normal life expectancy is generally accepted to be 95° C and this temperature is used to define the datum point for ageing assessment. A hot-spot temperature of 105° C has appeared in specifications for transformers, presumably to be used on normal cyclic loading; 160° C and 250° C are respectively the temperatures for earthing compensators and transformer short-circuit conditions. Opinion is hardening that existing loading guides based on 95° C are unduly conservative and some life tests have shown that a 20-year life-temperature of 120° C is possible.

Mr. Grierson stated that the immediate question was how accurately the hot-spot temperature could be assessed by calculation or winding temperature indicator. Inaccuracies in establishing the correct figure may well invalidate the essential difference between the two methods of assessing insulation ageing mentioned earlier.

To benefit from the test data so far established advantage could be taken of the inherent time-delay for oil to change in temperature, and to utilize higher winding temperatures under cyclic load conditions, calculations on a time/temperature basis being employed to find out whether loss of normal life expectancy is being incurred, and, if so, the extent of this loss.

Calculations on load curves show the importance of selection of transformer capacity since considerable economies may be possible. One such curve for a large town in South Africa showed that a daily overload of 50% could be sustained without loss of normal life expectancy and without excessive oil temperatures. In this particular instance considerations other than that of temperature appeared to limit the load on the transformer.

Mr. Grierson ended by stating that there were four factors to consider. First, should not the rise in temperature of the oil be increased in protected-type units, with corresponding increase in resistance rise and hot-spot temperature? Secondly, is the basic level of temperature for 25-year life expectancy (at present taken as 95° C) too conservative? Thirdly, should not hot-spot temperatures up to the order of 140° C be utilized when the transformer load follows a definite load cycle, where ageing can be assessed and expected to follow the laboratory pattern? Fourthly, when the load will increase over a period of years, should consideration be given to the fact that in the later years some loss of life could be tolerated on cyclic loading to use up the useful life of the transformer?

General Discussion

The eleven speakers who took part in the ensuing general discussion endeavoured to provide answers to these questions. An important factor which had not been established with certainty was the transformer life expectancy in relation to hot-spot temperature. It was suggested that more attention be paid to the measurement of this temperature, the winding temperature indicator in general use being subject to errors of from 3 to 5° C, which in turn might lead to discrepancies of some 4 or 5 years in estimates of transformer life. Another factor tending to reduce confidence in specified hot-spot temperature ratings was the variation in the values quoted in different national standards, e.g. United States 95°; United Kingdom 105°; and Germany 115–120° C; it was assumed, moreover, that manufacturers would all claim the same order of lives for their transformers. One speaker recommended the replacement of the unsatisfactory winding-temperature indicator by an ambient-temperature-compensated safe-current limiter to be used in conjunction with a current element having the same time-constant as the transformer to be protected. Another contributor maintained that winding-temperature indicator readings should be quoted for each winding of the transformer; he thought also that more efforts should be made to prevent deterioration of insulation in the region of the hot-spot, for instance by improving the quality of conductor wrapping-papers.

A number of speakers stressed the fact that a great proportion of transformers, apart from generator transformers, were run as a rule only very lightly loaded and that British Standards for this reason were perhaps too conservative. These specifications were felt to require frequent revision; for the operator to make maximum use of his equipment, they should give him some guidance on the duration and percentage of permissible overload, taking also into account the conditions obtaining before and after the overload. New transformer steels now available should stimulate trial runs at heavy overloads. It was also suggested that the power to be derived from the transformer should be kept in view as much as the current, since transformer operating voltages could with advantage be stepped up without affecting temperature, the sole inconvenience then likely to arise being an increase in noise, which in any event would usually occur during busy periods. One speaker pointed out that the name-plate rating of the transformer often differed considerably from the thermal rating and suggested that these be made to tally more closely. It was subsequently mentioned that a relay device for indicating the thermal capacity remaining at any given date was in fact already being manufactured.

A REVIEW *of the 'Proceedings'*

Measurement and Control

A summary of the Chairman's Address delivered by Mr. W. Bamford, B.Sc., Member, to the Measurement and Control Section on the 11th October, 1955. A long abstract of the Address is published in this month's issue of the Proceedings, Part B.

THE CHANGE IN THE NAME OF THE SECTION TO "MEASUREment and Control" provides a useful opportunity to discuss its activities in relation to the prevailing circumstances of industrial production in this country. Despite the spectacular interest recently generated in the possibility of the automatic factory and the many references to a new industrial revolution, evidence of continuous evolutionary development is put forward in the Address, and a plea is made for a balanced judgment, based on true engineering principles, of making the most efficient use of both the men and the materials available.

Nevertheless, the inevitability of continued development in the use of automatic controls and, for many industries, of completely automatic production, follows from prevailing economic and social conditions. In order that the contemporary standard of living may be improved (an exact definition of that standard is not attempted), production must increase despite the absence of additional supplies of labour, in order to offset larger oversea payments, including those for coal, which was at one time an important earner of foreign currency.

Present-day developments are a reminder of the period of the Renaissance, when the invention of printing by movable type, coupled with improvements in the means of transport, gave a tremendous impetus to communication between man and man. In our day, the improvement in communication between man and the machine, by means of data processing, computers, and automatic controls, makes the speed of production proportional to the rate at which the machine can accept its instructions rather than the rate at which a man can transmit them by manual or quasi-manual methods.

We must take care, in considering the application of automatic control, that new techniques do not obscure the basic devices—the simple analogue computers and control systems—which can be adapted and applied to individual processes and machines.

Education of higher management to appreciate the facilities available, and their limitations, is a duty of the measurement and control engineer. Equally, he must be able to explain control systems to the operator who, no longer required to work the machine, should reach a higher grade of technician—one carrying out maintenance that is adequate to ensure both quality and quantity production. Each man must be supplied with information which he can understand and which, within the limits of his life and work, is acceptable to him.

The development of technicians is of paramount importance; the creation of the right atmosphere is equally vital. It is not advisable, when urging a nation-wide acceptance of the application of automatic controls for increased production, to speak of "labour saving"—all production improvements must, in the final issue, lead to the greater economic use of labour, for otherwise the products of that labour cannot be sold.

Apart from the application of automatic controls in actual production, many of the techniques employed have further fields of use, some not yet exploited. As an example, computers may have a great part to play in the practical study of national economies, where notoriously the controls which are imposed are too late, and almost always incorrect, taking little note of either the direction or the magnitude of the rate of change in conditions.

The responsibility of the measurement and control engineer is considerable. It is necessary that the work of the research scientist should be made available quickly. The rate of progress is so high and the amount of data so great that assimilation is difficult, particularly to the non-specialist who may have to make decisions as to the use of new discoveries. Co-operation is essential, and greater use must be made of joint meetings, at which numbers of papers may be presented and discussed. Otherwise the time lag and the loss of interest may have serious results. Above all, we must not forget the limitations of the individual human mind, and the questions posed by T. S. Eliot in the following words:

> Where is the Life we have lost in living?
> Where is the Wisdom we have lost in knowledge?
> Where is the Knowledge we have lost in information?

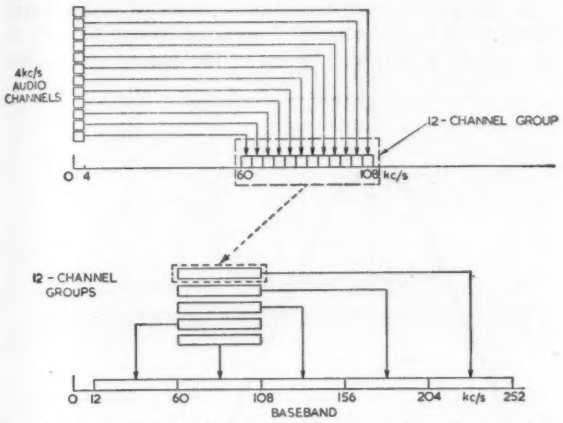
Radio Relay Systems

A summary of the Chairman's Address delivered by Mr. H. Stanesby, Member, to the Radio and Telecommunication Section on the 31st October, 1955. The Address is published in this month's issue of the Proceedings, Part B.

THE CROSS-FERTILIZATION OF IDEAS BETWEEN LINE- AND radio-communication techniques is most valuable, and the transformation of the Radio Section into the Radio and Telecommunication Section will benefit telecommunication as a whole.

Initially, long-distance line-communication systems provided only one audio-frequency telephone channel per pair of conductors. Later, valve amplifiers were introduced at intervals along routes to increase the

distances that could be covered. In due course, after the development of single-sideband technique, frequency-division-multiplex (f.d.m.) was introduced, and nowadays up to 60 channels per pair can be provided over balanced-pair cables, and hundreds of channels per pair over coaxial cables. The channels are assembled side by side in the frequency spectrum by a frequency-translation process which is carried out in two or more stages. Fig. 1 illustrates the process when applied to balanced-pair cables.



1 *Assembly of telephone channels for balanced-pair-cable systems*

In large telecommunication networks considerable numbers of channels are likely to be extended from one line system to another. International agreement is therefore desirable on the way in which channels shall be assembled, so that a number of channels can be transferred *en bloc*, instead of one at a time at audio frequencies, which is much more expensive. The C.C.I.F. has studied this matter and has recommended characteristics which facilitate such interconnections.

In designing multi-channel line systems, great care must be taken to avoid mutual interference between channels due to non-linearity in the common transmission path, and the repeaters, therefore, take the form of highly-linear negative-feedback amplifiers.

Television, also, can be transmitted over coaxial cables, but the signals have to be raised somewhat in frequency before transmission, to avoid interference which may be picked up on the cables at the lower frequencies.

Radio-relay systems of limited capacity have been used in internal telecommunication networks for many years, but since the 1939–45 War systems have come into use which are capable of transmitting large numbers of telephone channels, or television. For telephony, such systems make use of f.d.m. techniques similar to those used for cables, but they transmit television without changing the frequency of the signals as must be done for cables.

Large-capacity radio-relay systems generally provide two or more broad-band channels for each direction of transmission; and each such channel may be capable of accommodating television or hundreds of telephone channels. Frequencies of 2000 Mc/s or more are used, which make it possible to employ highly directional aerials. Relay stations are provided at intervals of about thirty miles along the route, their locations being so chosen that a line of sight can be obtained over each section between aerials mounted at the tops of towers. A typical intermediate-relay station is illustrated in Fig. 2.

2 *Aerial installation and building for 4000 Mc/s radio-relay system*

Special valves are needed for use at such high frequencies: reflex klystrons for generating oscillations, and close-spaced triodes or travelling-wave valves for amplification. Frequency modulation is employed, which makes it quite unnecessary to avoid amplitude non-linearity in the paths traversed by the modulated carrier. On the other hand, any non-linearity in a phase/frequency characteristic over the band occupied by the signal tends to give rise to intermodulation and hence interference between the channels when multi-channel telephony is transmitted. The requirements for transmitting television are less severe, however.

Clearly it is desirable to adopt characteristics that will facilitate the connection of radio-relay systems one with another and with land-line systems. This involves international agreement on various preferred radio-relay-system characteristics, including the capacities of the systems, the way in which broad-band channels, and telephone channels within individual broad-band channels,

should be assembled in the frequency spectrum, the intermediate frequency that should be adopted, and the impedances and levels at possible interconnection points. These matters are occupying the close attention of the C.C.I.R., with the co-operation of the C.C.I.F. where matters of common interest are involved.

If radio-relay systems are to play a big part in international and national telecommunication networks, manufacturers and administrations alike must be given some idea of the characteristics that are preferred. The time may not be ripe to finalize standards for equipment that is still in the formative stage, but it is desirable to adopt a limited number of preferred characteristics, with the intention of reviewing, and if necessary revising and extending, them in a few years' time.

Study of Radiocommunication by Ground Back-Scatter

A short review of two Radio and Telecommunication Section papers (Nos. 1914 and 1915) entitled "A Study of Ionospheric Propagation by Means of Ground Back-Scatter," and "The Technique of Ionospheric Investigation using Ground Back-Scatter," by E. D. R. Shearman, B.Sc.(Eng.), Associate Member. The papers were published separately in October, 1955, and they will be republished in Part B of the Proceedings.

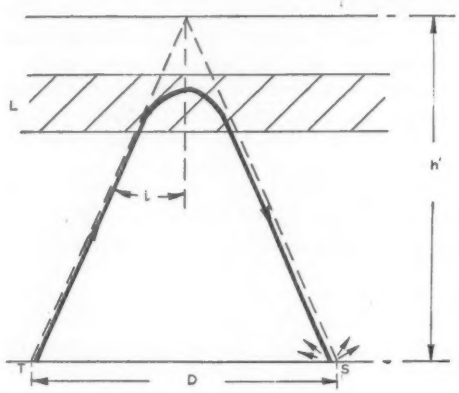
AN UNDERSTANDING OF THE PROCESS BY WHICH HIGH-frequency radio waves travel around the world is essential for the efficient development of long-distance radio-communication services. A new experimental technique has been developed for studying long-distance radio propagation without the co-operation of a distant receiving or transmitting station. By using this technique it is possible to determine, for a particular transmitted frequency, the parts of the earth's surface which the transmitted energy is reaching, and with which radio-communication is therefore possible.

In the h.f. band (3–30 Mc/s), radio waves emitted at a sufficiently small angle of elevation above the horizon are reflected back towards the earth's surface by the ionosphere, reaching the ground at a distance. Between the transmitter and this distant *illuminated zone* of the earth, there is a *skip zone* where no signals can be received from the transmitter. The distance to the far edge of the skip zone—the *skip distance*—increases with frequency up to a limiting distance of about 3 500 km; for higher frequencies all the energy radiated escapes through the ionosphere into space. For successful communication over distances up to 3 500 km, the frequency must be low enough to give a skip distance less than the distance from the transmitting to the receiving station, so that the latter is always in the illuminated zone.

Propagation to greater distances takes place by successive reflection from ionosphere and ground, the waves travelling round the curve of the earth in a series of hops.

The chief complication in h.f. communication arises because the height and reflecting properties of the various ionized layers comprising the ionosphere change with latitude, local time, season and sunspot activity. Transmission frequencies thus have to be changed at intervals throughout the day if communication with a distant station is to be maintained. A direct method of measuring skip distance, such as that provided by back-scatter observations, would be of great value for studying the complicated behaviour of radio circuits of this kind.

In the back-scatter technique, pulses of radio waves are emitted from an aerial T directed along the path to be studied, as in Fig. 1. Most of the energy striking the



1 *Ray path for ground scatter reflected by a plane layer*

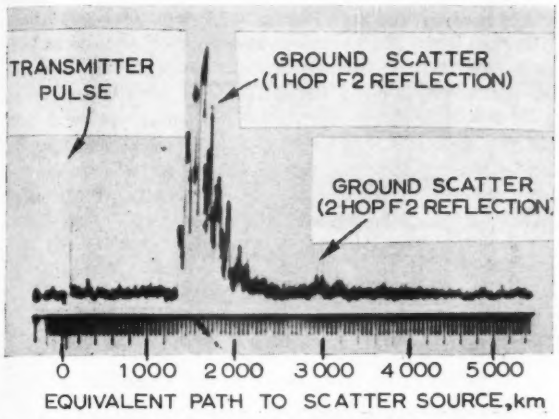
ground in the illuminated zone is reflected onwards, but irregularities on the earth's surface at S such as hills, trees and ocean waves, scatter a small fraction of the energy. Some of this scattered energy returns by way of the ionosphere to the neighbourhood of the transmitter where it can be detected in the form of echoes of the transmitted pulse. By measuring the time delay between the emission of the pulse and the reception of the first echoes to return, the oblique range to the far edge of the skip zone is determined, and hence, with a knowledge of the layer height, the skip distance is determined.

The type of echo pattern received is shown in Fig. 2, which was obtained with a transmitted pulse of 150 kW power and 100 microsec duration, by using a horizontal rhombic aerial for both transmission and reception. The time-base was calibrated directly in oblique range for convenience. The shape of the echo pattern is characteristic, a sharp leading edge corresponding to the high-intensity echoes from the near edge of the illuminated zone, the amplitude falling off with increasing range. A weak group of echoes from the ground areas illuminated by two-hop rays can be seen at 2 900–3 200 km.

A theory of the propagation of back-scatter has been developed by the author in which the relationship between echo time-delay, oblique range and ground range is found. From this theory curves have been calculated which show the correction to be subtracted from the

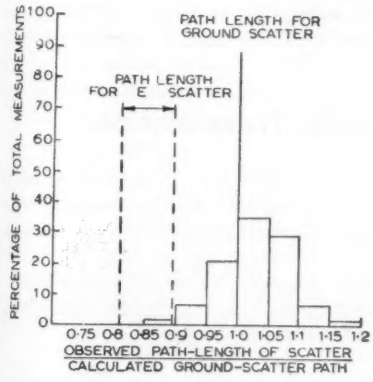
oblique range of the leading edge of the scatter pattern (1350 km in Fig. 2) to obtain the skip distance. This correction is about 150 km for F-layer propagation over distances greater than 1500 km, and about 50 km for E-layer propagation over distances greater than 500 km. It is concluded from this analysis that the back-scatter observations should yield good accuracy ($\pm 3\%$) in the measurement of skip distance.

The theoretical analysis also provides a method for



2 *Scatter pattern observed on normal time-base display*
Winter noon. Rhombic aerial, 80° E. of N. 18·5 Mc/s.

testing experimentally the conclusion of other workers that the scattered echoes come from the ground and not from the top of the E layer as was thought formerly. Fig. 3 summarizes the results of such experiments. It will



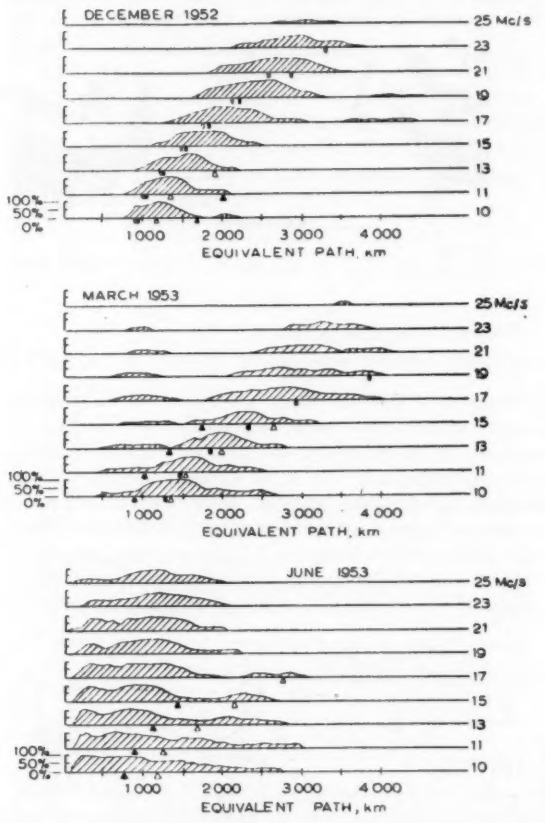
3 *Histogram of observations to locate sources of scatter*

be seen that the actual path length (oblique range) of the scattered echoes coincides with the value expected for scatter from the ground and not from the top of the E layer.

A further theoretical study has been made of the factors governing the amplitude of the scattered echoes, including the important effect of ray focusing, which is responsible for the high intensity of the echoes from the skip distance.

The scattering irregularities may be considered on the basis of a simplified model, hemispherical bosses on a conducting earth plane being chosen for convenience. An approximate calculation of the number and size of such bosses required to give the observed echo strength indicates that the irregularities present on land and sea are sufficient to account for the amplitude of the echoes.

Daily noon observations of ground back-scatter were obtained for a number of frequencies over a period of



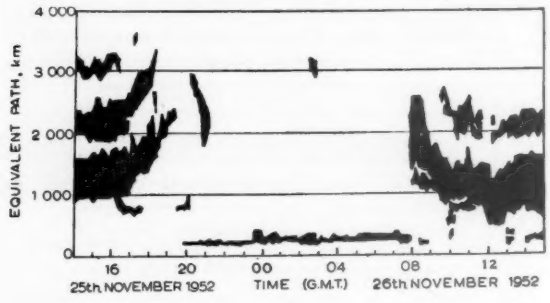
4 *Relation between percentage of occasions on which scattered echoes were seen and range of the echoes*

Time of observations, noon. Aerial, rhombic, directed 80° E. of N.
▲, E reflection
△, F1 reflection
} For direction of centre of main lobe of aerial.
■, F2 reflection
□, F2 reflection. For direction of southern extremity of main lobe.
The symbols represent the shortest range for scattered echoes propagated by way of each ionospheric layer (calculated from previously published predictions).

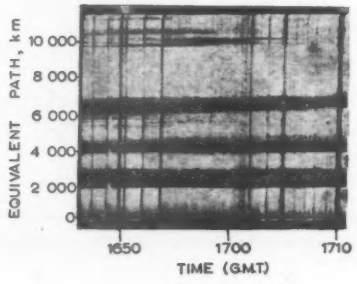
one year. The results of three months typical of winter, equinoctial and summer conditions are summarized in Fig. 4, and illustrate the very marked changes occurring through the year. The graphs give no indication of

amplitude, but show the percentage of occasions on which scattered echoes were seen, as a function of range. In December, propagation was taking place by the F2 layer (300–400 km high) only, and the range of the scatter, and therefore of the illuminated area of the ground, can be seen to increase with frequency up to a limit of 3 500 km. On a few occasions two-hop echoes were received at 17 and 19 Mc/s. In March, the range of the F2-reflected ground scatter has increased, and on a few occasions ground scatter reflected from sporadic clouds of ionization (Es) in the E layer (100 km high) was seen at a shorter range. In June, no F2 reflected ground scatter was seen, although on 30–50% of occasions propagation by way of the F1 layer (200 km high) was observed. The most striking feature in June, however, is the presence on nearly all occasions of Es-reflected scatter up to a frequency of 25 Mc/s. Short-range direct echoes from the E layer are also present.

Much useful information is yielded by a back-scatter sounder if a continuous recording technique is used. This provides records in the form of a graph of the range of scattered echoes against time of day. Fig. 5(*a*) illustrates the changing echo pattern during a 25-hour transmission on 10 Mc/s. Scattered echoes (shown as dark areas) were received from parts of the earth's surface illuminated by rays travelling by one, two and three hops. The echoes are seen to increase in range and disappear at dusk, when the ionizing influence of sunlight is removed, and to reappear and decrease in range at dawn. A short length of an actual record is shown in Fig. 5(*b*) and illustrates the very great range of echoes sometimes observed. The path length of the fourth group of echoes is 10 000 km, corresponding to the range of Malaya along the great circle through the aerial beam.



a



b

5 *Continuous recording of scatter*

(*a*) 10·05 Mc/s. Rhombic aerial directed 289° E. of N. (*b*) 4-hop scatter at 10 000 km range. 17·00 Mc/s. Rhombic aerial directed 80° E. of N.

The back-scatter technique can also be used to measure the maximum usable frequency for communication over a given distance. The frequency of transmission is varied until the range of the leading edge of the echo pattern corresponds to the required distance. Fig. 6 shows the results of an experiment of this kind, in which the maximum usable frequency for a path length of 3 000 km was measured continuously for a period of 26 hours.

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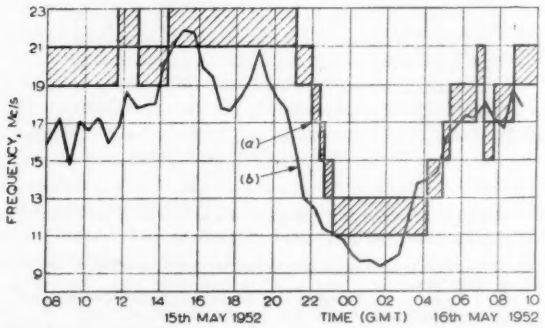


6 *Measurement of maximum usable frequency for a path length of 3 000 km*

(*a*) By back-scatter. (*b*) From Lindau vertical-incidence measurements.

Reciprocal Radio Transmission

A short review of a Radio and Telecommunication Section paper (No. 1901) entitled "An Experiment to Test the Reciprocal Radio Transmission Conditions over an Ionospheric Path of 740 km," by R. W. Meadows, B.Sc.(Eng.), Associate Member. The paper was published separately in September, 1955, and it will be republished in Part B of the Proceedings.

IN THE PRESENCE OF A MAGNETIC FIELD AN ELECTRON BEING spun round by a rotating electric field of given strength will take up a different equilibrium radius of rotation if the sense of rotation of the electric field is altered. A medium containing free electrons may then be regarded as non-linear, and the reciprocal theorem does not apply; in other words, propagation in reciprocal directions is different. For the case of the ionosphere, the earth's magnetic field causes a wave to be split into two components, the *ordinary* and *extraordinary*, propagated with

different velocities. Either of these components is theoretically reciprocal when considered separately; the combination, however, is not, since the sign of the difference between the component velocities is related to the direction of the earth's magnetic field and not to the direction of propagation of the wave.

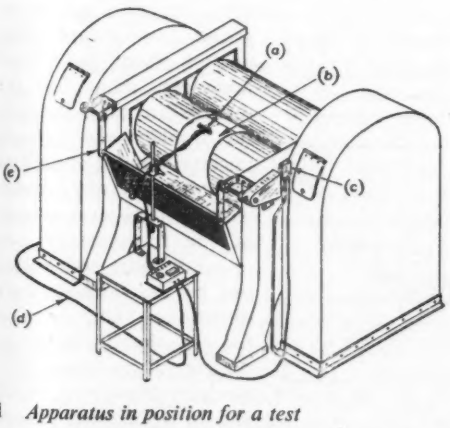
The prediction that each component separately should be reciprocal was tested by comparing the fading of ordinary-ray pulses received at Inverness from Slough with corresponding pulses received in the reverse direction. The fading pattern at Inverness was scanned and relayed to Slough over a Post Office trunk line, and an aerial common to transmitter and receiver was used at each terminal to avoid space-diversity effects. The ordinary-ray fading was found to be reciprocal for 99% of the time; the odd 1% was probably due to the formation of some extraordinary component by reflection from rapidly changing sharp boundaries.

621.396.11 : 621.396.812.3

Timing Control Systems for Rotating Equipment

A short review of a Utilization Section paper (No. 1800) entitled "Timing the Operation of Control Systems associated with Rotating Equipment," by C. Cuthbert, B.Sc., A.R.I.C., and D. A. Picken, Member. The paper was published separately in March, 1955, and it will be republished in Part A of the Proceedings.

IT IS DESIRABLE OFTEN TO KNOW THE TIME INTERVAL between switching operations and sometimes to relate these to distance travelled—an example of this is with a lift. In the rubber industry, where heavy rolls are used to break down rubber and incorporate chemicals into the mixing, there were many serious accidents due to the operator being trapped between the rolls. A guard was devised* which, when pressed, actuated a braking device that stopped the rolls before maiming occurred.

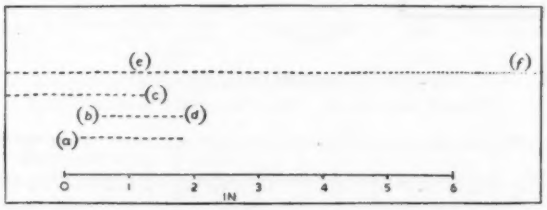


1 *Apparatus in position for a test*

(*a*) Six steel styluses.
(*b*) Teledeltos paper.
(*c*) Emergency switch.
(*d*) Connections to relays and micro-switches.
(*e*) Safety bar.

To assess the value of the brakes a strip of electro-sensitive Teledeltos paper is attached to the roll, and a set of steel styluses is made to touch the paper as shown in Fig. 1. One of these styluses is connected to a 50 c/s supply by potentiometer circuit so arranged that the r.m.s. value of the voltage applied is about 170 volts. If the paper is moved and the potential is applied a mark appears whenever the voltage exceeds about 170 volts instantaneous value. Thus the distance between comparable points on the markings indicates the distance travelled in half a cycle, i.e. 1/100 of a second.

Other styluses are used to indicate the time of operation of the trip bar, the supply to the motor, the supply to the brakes, the movement of the brakes, etc., and the resulting traces are analysed to determine the acceleration forces, the delay times and the total stopping distance. A typical trace is shown in Fig. 2.



2 *A typical trace of the timing of the equipment associated with the stopping of a rubber roll*

(*a*) Emergency switch closed, 0·00 sec.
(*b*) Relay operated, 0·02 sec.
(*c*) Micro-switch opened by movement of break shoes, 0·07 sec.
(*d*) Power supply cut from motor, 0·12 sec.
(*e*) Timing circuit.
(*f*) Mill stopped.

This diagram is a copy of a trace, and has been drawn with greater clarity.

This simple technique has proved very reliable and accurate and has disclosed the need for care in designing such braking systems. In one system some 75% of the kinetic energy is dissipated in 1/20 sec during a total breaking period of $\frac{1}{2}$ sec, owing to the time constants of the d.c. motor and the braking contactor.

Another interesting phenomenon is the problem of brake glide with electro-mechanical brakes. In some braking systems the shoes did not brake until they had been in contact with the braking drum for approximately 1/5 sec. This phenomenon, known as brake glide, is possibly associated with the liquefaction of the bonding material of the brake lining at the very high temperatures associated with high brake pressures.

621.316.719 : 621–52

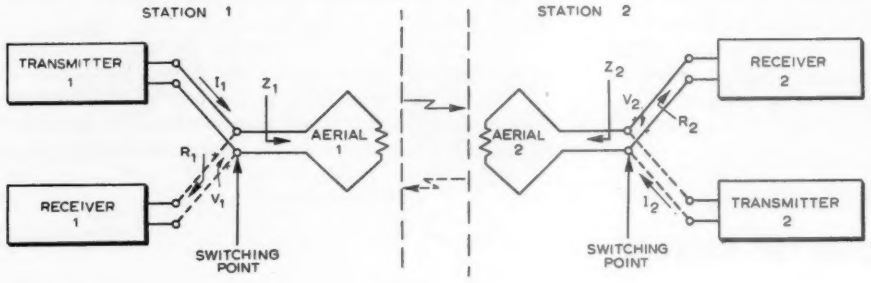
* By the National Joint Industrial Council for the Rubber Industry.

Attenuation of Radio Signals

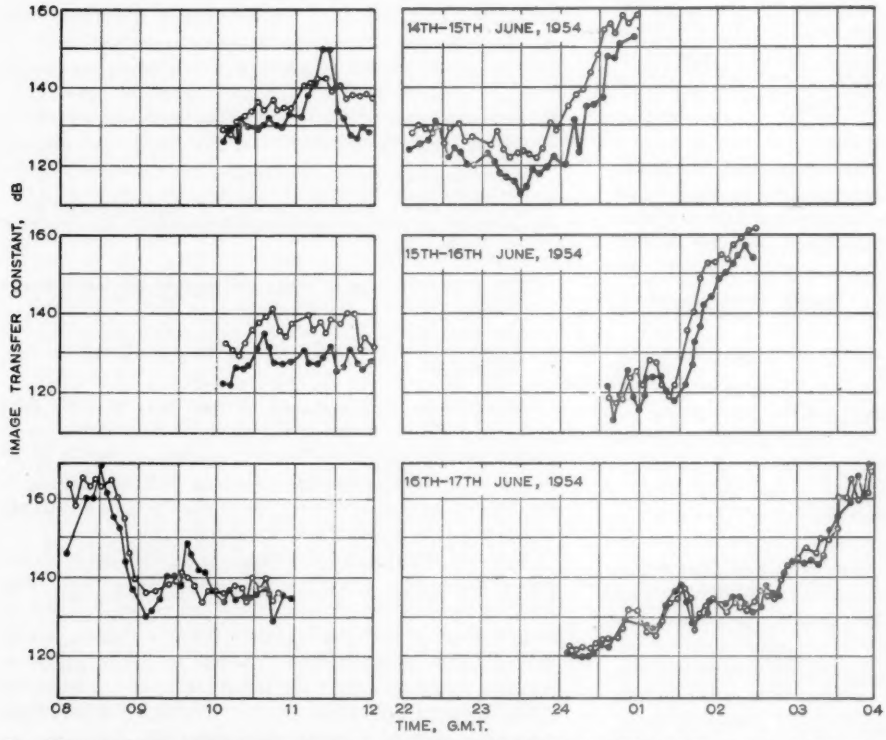
A short review of a Radio and Telecommunication Section paper (No. 1904) entitled "An Experimental Test of Reciprocal Transmission over Two Long-Distance High-Frequency Radio Circuits," by F. J. M. Laver, B.Sc., Member, and H. Stanesby, Member. The paper was published separately in October, 1955, and it will be republished in Part B of the Proceedings.

TESTS HAVE BEEN CARRIED OUT UNDER CONTROLLED conditions to see whether the attenuation of h.f. signals sent over long-distance radio paths differs according to the direction of transmission (Fig. 1).

At each end of the radio circuit there was a single aerial and feeder which could be switched either to a transmitter or to a receiver tuned to the same frequency. Transmissions of an unmodulated carrier wave lasting for two minutes were made alternately from each end of the circuit, with intervals of 30 sec between transmission to allow for change-over. The current delivered by the transmitter to the aerial at one station and the p.d. across the input terminals of the receiver at the distant station were monitored. The output signals from the receivers were measured with recording milliammeters, using time-constants of the order of 15 sec to smooth out the more rapid variations in signal strength, and the recorders were calibrated in terms of input-signal voltage. The results obtained (see Fig. 2), both across the North Atlantic and between Australia and the United Kingdom, show that at times the loss in both directions is substantially the same, and that at other times the loss difference could rise to values of the order of 10 d B. These differences appear to persist over periods of a few hours or a few days, and to occur quite frequently. It happens that the results obtained so far, both on the North Atlantic and Australia routes, have yielded figures for attenuation that are, on the average, greater for outward transmission from the United Kingdom than for the reverse direction. Whether this would always be so is uncertain, but it is difficult to conceive any reason why the long-term average of the transmission loss over any radio path should not be the same in both directions. There is room for considerably more experimental and theoretical work on this subject, which should be of great interest to ionospheric physicists.



1 *Test arrangement for radio-reciprocity tests*



2 *Measured image transfer constants (i.e. loss) for United-Kingdom/United-States North Atlantic Route, 13 332 kc/s, during the period 14th–17th June, 1954*

• United States→United Kingdom. ○ United Kingdom→United States.

621.396.2 : 621.396.11

Ionospheric V.H.F. Communication

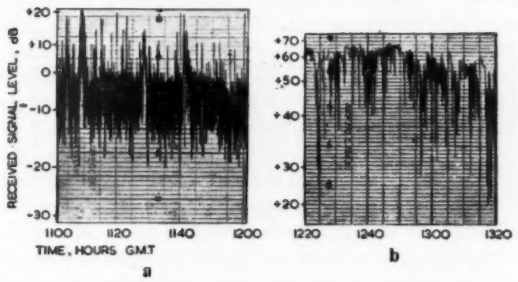
A short review of a Radio and Telecommunication Section paper (No. 1920) entitled "V.H.F. Propagation by Ionospheric Scattering and its Application to Long-Distance Communication," by W. J. Bray, M.Sc.(Eng.), Member, J. A. Saxton, D.Sc., Ph.D., Member, R. W. White, B.Sc., F.Inst.P., Associate Member, and G. W. Luscombe, B.Sc.(Eng.), Associate Member. The paper was published separately in October, 1955, and it will be republished in Part B of the Proceedings.

IN THE PAST FEW YEARS THERE HAS BEEN CONSIDERABLE interest amongst radio engineers in the possibility of using very-high-frequency waves for communication over long distances. An account was published in 1952 of American work by D. K. Bailey and his co-workers, in which the continuous reception of signals at a frequency near to 50 Mc/s over a distance of 1 245 km was reported; and this drew attention once again to the patchy distribution of electron density in the E-region of the ionosphere, for it appears that the observed transmissions resulted from the scattering of radiation by these irregularities in the medium. Although T. L. Eckersley, 25 years ago, emphasized this feature of the E-region, little has been done in the intervening period to make positive use of scattering for communication purposes.

The paper describes an investigation carried out jointly by the Post Office and the Radio Research Station of the Department of Scientific and Industrial Research, in which the characteristics and possible uses for communication purposes of ionospherically scattered signals have been examined. The transmitter was located in the Shetland Isles, and signals were received mainly at Slough and at Jersey in the Channel Islands. Observations were also carried out on board ship, in collaboration with the Admiralty, to determine the maximum range of reception and the lateral spread of energy from the main transmitted beam.

A signal transmitted by the scattering process in the ionosphere is of extremely variable amplitude. There is always present what may be called a residual or "background" component, provided high transmitter power and a sensitive receiver are used, and this has been observed, at a frequency of 41 Mc/s, to vary over paths of 1 000 to 1 200 km throughout a total range of some 70 dB. This range includes slow changes during the day and with season. The rapid fluctuations observed during a relatively short period, say an hour or so, are usually from 20 to 40 dB. They occur at a rate of about 10 dB per second, and fluctuations in the signal level of more than about ± 6 dB occur at rates of about 30 per minute. For an effeotive radiated power of 350 kW (at 41 Mc/s), and with a receiving aerial having a theoretical plane-wave gain of 18 dB, the noon median level of the background signal over a 1 200 km path from the north to the south of Great Britain, appears, in the summer months, to be about 0 to -5 dB relative to 1 μV across a 75-ohm receiver input. The corresponding level in the winter is about -5 dB, and at the equinoxes -10 to -15 dB. The daily minimum signal occurs around 2000 h G.M.T. and the average difference between the daily maximum and minimum values varies from 10–15 dB in summer and winter to not much more than 5 dB in spring and autumn.

Superimposed on the background signal are numerous "bursts" of signal, lasting generally for various times up to perhaps half a minute, when the amplitude increases by 40 dB or more, relative to the background. It is considered that these bursts are associated with reflections from the ionized trails of the larger meteors. Fig. 1(*a*)



1 *Samples of chart records at 41 Mc/s*
(*a*) Examples of burst-type signals. (*b*) Sporadic E signal.

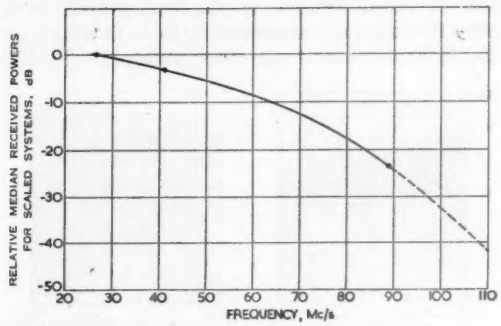
shows a sample recording of the background signal with burst signals clearly in evidence. At times when there are clouds of sporadic E ionization present in sufficient intensity, very strong signals, 60–100 dB above the background, occur. These can persist for periods up to an hour or more depending upon the density of the sporadic ionization and the frequency of the transmission. Fig. 1(*b*) shows the characteristics of the recorded signal at such times.

There is as yet no general agreement concerning the cause of the fluctuations of electron density which lead to the production of the background signal. A number of agencies have been proposed of which the two most important are meteors and turbulence due to winds known to exist in the ionosphere. The effects of the trails of ionization of the larger meteors are unmistakable, and it seems reasonable to suppose that a contribution, at least, to the background signal arises from the less intensely ionized trails produced by the multitude of smaller meteors which are continually bombarding the upper atmosphere. A number of seasonal and diurnal characteristics of the signal show a correlation with meteoric activity. On the other hand the variation of the signal during daylight hours suggests that scattering due to turbulence may play a more important part at such times.

Measurements at frequencies of 27, 41 and 89 Mc/s have shown that the scattered power decreases rapidly as the frequency increases, other conditions being constant. Fig. 2 shows how the relative received power may be

expected to vary over a 1000 km path, the radiated power being constant, and the transmitting and receiving aerials being scaled to have the same directive properties at each frequency. From these results it may be deduced that the range of frequencies likely to be most useful for applications of this mode of propagation is approximately 25 to 60 Mc/s.

The performance of directive aerials also seems to be a variable quantity. The observations show that it is very seldom that such aerials have as much gain as they would



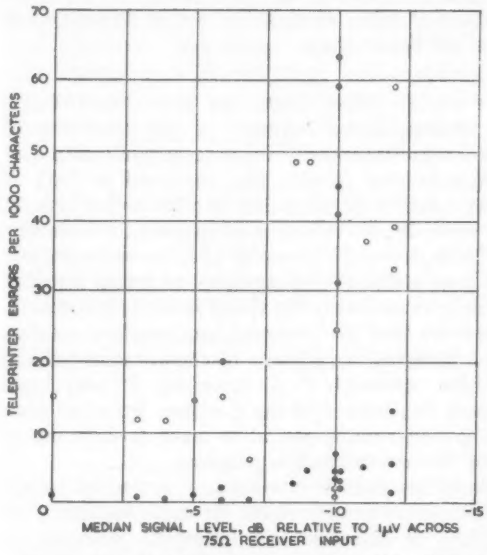
2 *Variation of transmission loss with frequency for systems with aerials having dimensions scaled according to the wavelength*

have if plane-wave transmission were involved; in fact the average value of the effective gain is only about the square root of the plane-wave gain. It appears that there is little point in increasing the gain of the transmitting aerial unless a receiving aerial of similar gain is used, and vice versa.

What may be termed the effective reflection coefficient of the E region for scatter-type propagation is very low, only of the order of 10^{-4} or 10^{-5}; this means that only transmission involving one excursion into the ionosphere and back is possible, and consequently the maximum useful range of transmission is not much more than 2000 km. This conclusion has been confirmed by experimental observations.

From experimental tests of the possibility of transmitting frequency-shift telegraphy signals (standard 50-baud 200 c/s shift) by means of ionospheric scattering, it has been concluded that a satisfactory teleprinter service using the background signal at a frequency of 41 Mc/s could be established on a continuous basis by increasing the transmitter power and combined aerial gain by a total of about 18 dB relative to those used in the investigation. Such an increase seems feasible, and could be achieved, for example, by the installation of a 60 kW transmitter, and by using transmitting and receiving aerials each having plane-wave gains of 26 dB. There is a marked advantage in using two aerials for diversity reception compared with a single receiving aerial, as shown in Fig. 3. The diversity may readily be obtained by directing one aerial a few degrees to one side of the great-circle path from transmitter to receiver, and the other aerial a few degrees to the other side. The continuous operation of high-speed single-channel telegraphy links, or multi-channel time-division links is, however, unlikely to be satisfactory, except perhaps for links carrying only a few channels.

It is much more difficult to set up a continuous telephony circuit, even carrying only a single channel with a band-width of about 3 kc/s. The transmitted power required to do so is hardly practicable and would



Comparison of teleprinter errors per 1000 characters with and without diversity operation (41 Mc/s)

● With 2-aerial diversity.
○ Without diversity (average of two channels).

in any case be uneconomic. However, a service of this simple form could be made available for perhaps 50% of the time, confined mainly to the daylight hours. Single-sideband amplitude modulation appears to give slightly better results than phase modulation, and both are definitely superior to frequency modulation.

It must be emphasized that these communication performance estimates apply strictly to the experimental link investigated, from the Shetland Isles to the Channel Islands, and to a frequency of 41 Mc/s; they would require modification for other frequencies and for other path lengths and geographical locations. Some improvement in performance may be expected by the use of frequencies less than 41 Mc/s, though the improvement is not likely to be large; on the other hand, at higher frequencies the system performance would deteriorate rapidly.

Other services, of course, make use of the frequency band 25–60 Mc/s, which seems the band most useful for the application of ionospheric scatter propagation; and at times of sporadic E ionization, or of intense F2 ionization in the years of maximum sunspot activity,

there would be the possibility of mutual interference between links using scatter propagation and the other services. This might to some extent be mitigated by the use of highly directive aerials for the scatter links, and by the use of the highest feasible frequency.

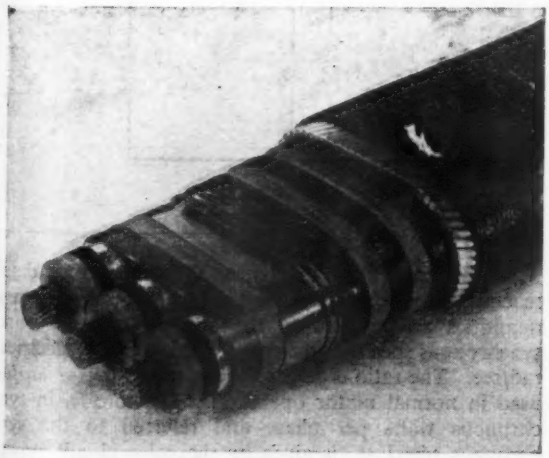
In considering the possibilities of communication one further feature of the scattered signal should be borne in mind. Although it appears that the signal persists at times of geomagnetic disturbance and ionospheric storms—indeed it has been suggested that it may then even be enhanced—it has been observed that an auroral display over the transmission path produces such violent and rapid fading of the scattered signal that communication of any kind becomes practically impossible.

621.396.11

Flat Pressure Cable

A short review of a Supply Section paper (No. 1884) with the above title, by J. S. Møllerhøj, M.Sc., Member, A. M. Morgan, B.Sc.(Eng.), Associate Member, and C. T. W. Sutton, M.Sc.(Eng.), Member. The paper was published separately in July, 1955, and it will be republished in Part A of the Proceedings.

THE CABLE INSULATION PROBLEMS ASSOCIATED WITH THE transmission of electric power at high voltages have led to many designs of oil- and gas-impregnated paper-insulated cables, all of which require auxiliary equipment to eliminate or reduce the difference in level of electric strength at power-frequency voltages between an oil-impregnated paper dielectric in a virgin condition and one in an aged condition. A large difference occurs with cables of solid type owing to void formation resulting from cyclic heating of the cable, which consists of an aggregate of materials of varying elastic and thermally expansive properties. The flat pressure cable does not require any auxiliary equipment, and represents an attempt to provide an ideal construction in which the cable is self-compensating to the variations in volume of the dielectric occurring in service.



1 *Specimen of 132 kV submarine cable*

The construction of a 132 kV submarine cable is shown in Fig. 1. Three paper-insulated screened circular conductors laid together side by side in flat formation are enclosed in the lead sheath, reinforced with non-ferrous tapes applied circumferentially together with two corrugated metal strips which are bound onto the flat faces by means of one or more wires. The insulation is impregnated with a low-viscosity oil after sheathing. Anti-corrosion protection is applied overall, together with jute serving and aluminium-alloy armouring. The jute serving and armouring are omitted on land cables.

When the cable is on load, the heat generated in the conductor causes the oil to expand and produces a radial deflection of the flat sides of the cable which act as uniformly loaded beams. The design is such as to ensure elastic deformation and the return of the flat side to its initial position when the load is removed.

The cable was first produced in Denmark, but in 1950 arrangements were made for a British manufacturer to produce the cable. Different conditions of operation and different bases of current rating in the two countries led to a development programme to enable a more economical design to be produced. A major portion of the paper is concerned with the results of this development programme, and data for determining the maximum permissible continuous-current loading of the cable for various conditions of installation are presented for the first time. At present some 109 miles of cable are in service, mainly in Scandinavia, and the service experience gained with these installations, which date back to 1941, is discussed. The authors examine the choice of materials for the various components operating with system voltages from 33 to 220 kV and briefly describe the method of manufacture.

The correct design of the cable accessories, i.e. the joints used to connect factory lengths of cable after installation and the porcelain sealing ends used for terminating the cable, are equally important components of the cable system. The paper describes the electrical and mechanical design of these accessories and the experience gained from them in service.

Very few faults have been experienced with the cables so far laid. No electrical breakdowns have occurred and the few instances of mechanical failure that can be cited were on an early installation and were associated with plumbing at cable joints; they could not be attributed to a fundamental defect in design.

With normal 3-core cables the individual cores are generally laid up together before sheathing. The flat pressure cable eliminates this process and allows much longer manufacturing lengths, which is a great advantage for submarine installations, where the number of joints must be kept to an absolute minimum. Further, this self-contained design avoids any possibility of the cable being crushed under high external pressure when the cable is laid in deep water. Ten different submarine

2 *Floating drum for 132 kV Øresund cable*

cables have been laid to date. In 1951 a 132 kV cable was laid between Denmark and Sweden—the first 3-core submarine cable for this voltage of any type to be laid. In 1954 a duplicate installation was made; in this cable the factory lengths were joined by means of flexible joints and the complete cable was wound on to a Pluto drum as was used in the Second World War. Fig. 2 shows the cable loaded on the drum. The paper gives details of this installation and of the equipment used.

Details of long-term stability tests with alternating current, direct current and impulse voltages indicate that the cable will continue to function satisfactorily over a period of many years. The future development of the cable with special reference to d.c. transmission and to the application of aluminium sheathing is discussed, and the possibility of alternative cable designs on the same functional principle is examined.

The general conclusion reached is that test and service experience indicate that the design of the cable is sound, but improvements can be made with a view to an even more economical design. The cable is particularly successful when used for submarine installations.

615.315.2

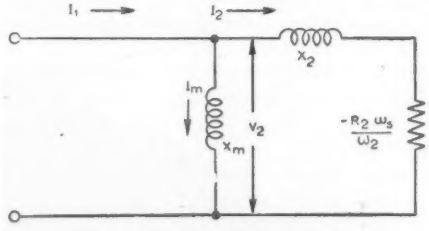
Dynamic Braking

A short review of a Utilization Section paper (No. 1885) entitled "The Dynamic Braking of Induction Motors," by D. Harrison, M.Eng., Ph.D., Associate Member. The paper was published separately in August, 1955, and it will be republished in Part A of the Proceedings.

AN INDUCTION MOTOR CAN BE ELECTRICALLY BRAKED BY exciting the stator windings with direct current, so that the machine becomes an alternator, the braking power being that dissipated in the rotor circuit. This is known as *dynamic braking* and is used on mine-shaft winders and industrial machines. Compared with the reverse-current or plugging method, it has the advantages that no reverse rotation is possible and that much less energy is dissipated in the machine. A disadvantage is that a source of direct current is required, although as far as industrial machines are concerned this is often conveniently provided by metal rectifiers.

The braking torques may be calculated by the standard alternator methods, but these may be tedious to apply or rather inaccurate, and the paper describes a simple method of calculation, based on the well-known induction-motor technique, which takes account of saturation and rotor reactance.

In the equivalent braking circuit shown in Fig. 1

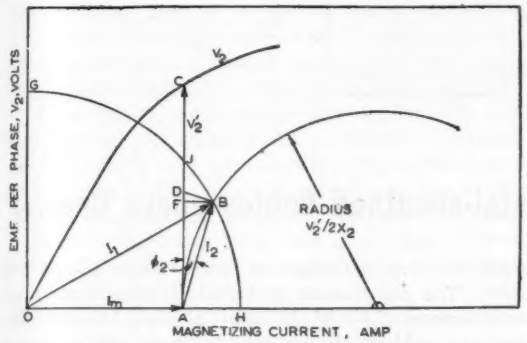


1 *Dynamic-braking equivalent circuit*

X_m is the magnetizing reactance, X_2 is the rotor leakage reactance, and V_2 is the rotor e.m.f. per phase. All these quantities are referred to the angular frequency and synchronous speed ω_s, the rotor speed being ω_2 electrical rad/sec. The ratio ω_2/ω_s replaces the slip $(\omega_s - \omega_2)/\omega_s$ used in normal motor operation. The torque, in synchronous watts per phase and referred to the synchronous speed ω_s, is given by the rotor circuit power $-I_2^2 R_2 \omega_s/\omega_2$, where I_2 is the rotor current per phase

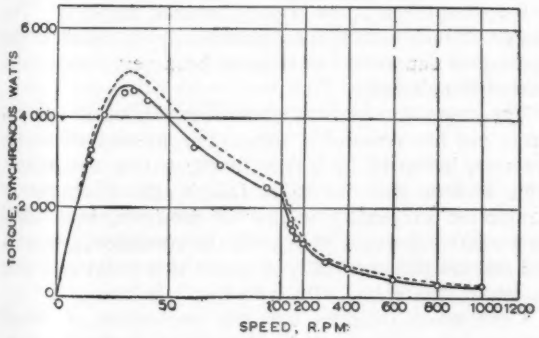
and R_2 is the rotor circuit resistance per phase. The equivalent resistance and the power are negative, because the torque is opposed in direction to the rotation. The relation between the direct excitation current and the equivalent r.m.s. current I_1 is given in the paper for different stator connections.

For unsaturated conditions X_m is constant and the torques may be calculated from the equivalent circuit fairly easily, but when X_m is not constant such calculations are laborious. This difficulty may be avoided by adopting the graphical construction shown in Fig. 2.



2 *Graphical construction for the calculation of dynamic-braking characteristics*

The curve OC shows the relationship between V_2 and I_m for the frequency ω_s, and OAB is the vector diagram corresponding to Fig. 1, for the particular e.m.f. $V_2' = AC$. For a given excitation I_1 is fixed so that B lies on the circle GBH, and since the rotor circuit of Fig. 1 has a fixed reactor in series with a variable resistor,



3 *Torque/speed characteristic*

Rotor short-circuited.
$R_2 = 0{\cdot}27$ ohm.
$X_2(40\,c/s) = 0{\cdot}45$ ohm.
Direct stator current = 10 amp.
—— Predicted, allowing for X_2.
– – – Predicted, neglecting X_2.
○ ○ Measured.
Note change of speed scale.

B also lies on the circle through A of radius $V_2'/2X_2$, so that the position of B can be determined.

The torque is

$$V_2'I_2 \cos \phi_2 = \text{AC (in volts)} \times \text{AF (in amperes)}$$

and if DB is drawn perpendicular to AB, the effective rotor resistance is

$$R_2\omega_s/\omega_2 = \text{AC (in volts)/AD (in amperes)}$$

By repeating the construction for different values of V_2' and of I_1, the torque/speed characteristics for given values of R_2, or the torque/resistance characteristics for given speeds, can be derived. If X_2 is neglected, the points B, D, F coincide with the point J, since the radius of the I_2 circle becomes infinite.

The results of a comprehensive series of verifying tests on a slip-ring motor, with and without external rotor impedances, are given in the paper. Fig. 3 shows the results for one set of conditions.

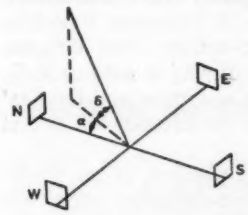
The time taken to come to rest under dynamic braking is proportional to the mean of the reciprocal of the torque, as explained in the paper, and, with torque/speed characteristics of the dynamic-braking type, calculations based on the mean torque are subject to large errors. The running-down time of slip-ring motors may be reduced considerably by inserting the whole or part of the starting resistance during braking, and the paper shows how the optimum resistance is calculated.

621.316.719 : 621.313.333

Direction of Radio Echoes

A short review of a Radio and Telecommunication Section paper (No. 1932) entitled "Automatic Recording of the Direction of Radio Waves Reflected from the Ionosphere," by J. A. Thomas, B.Sc., A.Inst.P., and R. W. E. McNicol, M.Sc., A.Inst.P., Graduate. The paper was published in November, 1955, in Part B of the Proceedings.

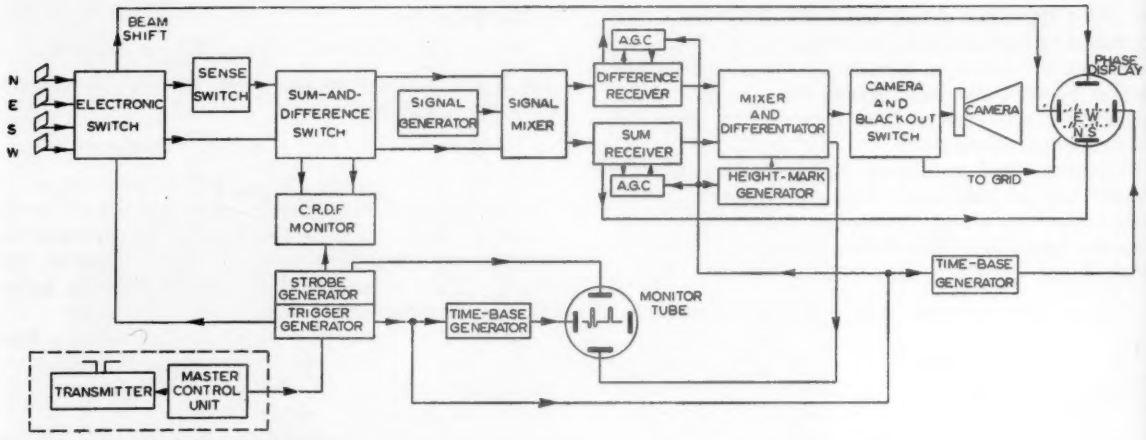
WHEN A RADIO TRANSMITTER AND RECEIVER ARE OPERATED in close proximity, the radio waves received after reflection by the ionosphere do not always arrive from vertically overhead. Isolated patches of intense ioniza-



1 *General layout of aerial system*

tion such as occur in the sporadic E region may give echoes with elevation angles as low as 45°, and frontal disturbances in the F region may likewise give non-zenithal reflections.

An equipment has been developed at Brisbane to provide automatic recording of slow changes in the



2 *Schematic of complete equipment*

direction of arrival of all the ionospheric echoes received when the transmitter is pulse-modulated. The direction of arrival is found from simultaneous measurements of the phase differences between the radio signals in two pairs of spaced loops arranged as shown in Fig. 1. The phase differences are measured by comparing the vector sum of the two signals with the vector difference, the ratio of these two quantities giving the cotangent of half the phase difference between the signals.

The complete equipment is shown schematically in Fig. 2. The r.f. signals from the loop aerials enter an electronic switch which passes signals from only one pair of loops at a time, e.g. N and S, or E and W, and which also provides synchronous beam shifting of the final cathode-ray display. The sum and difference of the pair of signals is then derived and each output passes to its own receiver. These two receivers do not require to be phase-balanced but merely gain-balanced. This gain-balancing is achieved by running each receiver with a special automatic-gain-control unit (A.G.C.), which operates on a fixed r.f. pulse injected by a pulse-modulated signal generator into both receivers. The rectified outputs of the two receivers are applied to a cathode-ray tube, the sum output to the vertical plates and the difference output to the horizontal plates. A horizontal time-base is also applied to resolve the echoes from different regions of the ionosphere. The display is automatically photographed for three minutes at a time, and the final result is an integrated record of the directions of arrival at three-minute intervals.

Since the only phase-sensitive portions of the equipment are the aerials and the pre-amplifiers (electronic switch and sum-and-difference unit), the equipment is stable enough to run without attention for several days. This fact, and the ability to provide information simultaneously on all echoes, makes the equipment particularly suitable for the measurement of slowly changing directions of arrival, and hence for the ultimate interpretation of a number of ionospheric phenomena.

621.396.11 : 621.317.34

Metal-sheathed Cables above Ground

A short review of a Utilization Section paper (No. 1814) entitled "The Installation of Metal-Sheathed Cables on Spaced Supports," by W. Holttum, M.Eng., Member. The paper was published separately in April, 1955, and it was republished in December, 1955, in Part A of the Proceedings.

THE RANGE OF TEMPERATURE DUE TO LOAD CYCLES CAN produce stress in the lead (including lead-alloy) sheath of a cable well in excess of its elastic limit, but experience indicates that no fracture results so long as the strain is well distributed, as occurs with cable buried in the ground. For cables with intermittent supports, close enough spacing to provide complete restraint would be uneconomic, and, except on very short runs, expansion is therefore taken up by sagging between supports. The design of such installations, particularly in regard to the spacing of supports, has hitherto been very much on a rule-of-thumb basis.

The inspection of a number of installations over 10 years old has revealed a substantial amount of sheath fracture, indicated by leaking impregnating compound. This seldom leads to cable failure, the discharge of compound preventing ingress of moisture, but, while cables have operated for years in this condition, probably the leakage will eventually diminish to a point at which moisture may enter, with consequent failure.

Observation indicates that the mechanism of sheath fracture consists in cyclic bending due to thermal expansion and contraction in single spans here and there. The explanation is that the support spacing is inadequate to enable the cable to sag under its own weight sufficiently to absorb the expansion in each span, so that it becomes a series of struts stressed to the point of collapse. As soon as one span collapses, it takes up the expansion of a number of spans on each side of it, leading eventually to fracture of the sheath. With wide enough spacing,

each span will sag independently without longitudinal movement, and, though the sheath strain cannot be uniform owing to the two points of inflexion, it is not excessive, and the expansion is absorbed without apparent injury. The life of a lead cable sheath under these conditions cannot be stated (one well-loaded installation over 50 years old is showing no sign of trouble), but no reason has been found to suggest that well-designed installations on spaced supports will not give satisfactory life. This is probably the most economical of any method of installation.

Geometrical considerations easily show that the larger the sag the smaller will be the amount of bending caused by a given expansion, so that the natural preference for the appearance of a straight run of cable with negligible sag between supports is contrary to sound engineering.

A means of determining the appropriate support spacing for any particular cable is therefore required, the principle being that the minimum permissible spacing is that at which each span will just take up its own expansion by sagging under gravity. A precise theoretical solution is not practicable, nor is a solution by direct experiment. The mechanical properties of lead are such that conventional beam theory does not apply, but, by making use of stress/strain relationships from researches into the creep properties of lead and its alloys, a formula has been derived which gives results supported by practical experience. The Table gives span lengths for

Calculated Spans for 3-Core Solid-Type Cable with Alloy E Sheath and Single Wire Armour

Voltage, kV	1·1 (belted)			11 (screened)		33 (screened)	
Conductor area, in^2.	0·1	0·3	0·75	0·1	0·5	0·1	0·5
Span, in.	63·5	76·1	92·4	77·8	93·0	104·1	114·6

a representative selection of cables to B.S. 480. There is no reason to suppose that spans a good deal longer than these minimum values, with due regard to bearing pressure on the sheath and tension in the cable, would not be satisfactory.

Fig. 1 shows a typical case of a collapsed span with compound leakage, and Fig. 2 shows part of the 50-year-old installation mentioned above.

Longitudinal movement is sometimes detectable from the impression made by the supports on the serving, but, as the expansion is only about 0·04%, a more definite check may be made by measuring the sags at two widely different temperatures, and, if there is no movement, the difference of the squares of the sags, as percentages of the spans, should be about equal.

Published researches do not indicate the alloy of lead which will best stand up to slow repeated strain, but there

1 *Two-cable installation showing collapsed middle span of front cable*

2 *Cable taking up expansion by sagging in each span*

is experience to indicate that unalloyed lead is inferior to alloy E (containing 0·4% tin and 0·2% antimony). Steps are being taken to solve this problem.

While wire armour probably very slightly reduces the flexing near supports if there is a large sag, there is no reason to regard it as necessary, and single-core cables must, of course, do without it. Observations of service experience have been confined to lead (including lead alloy)-sheath cables, for aluminium-sheath cable which has been similarly erected is yet limited in quantity and of recent date. Aluminium-sheath cables are dealt with theoretically, and it is shown that, with suitable span length and initial sag, the flexing can be kept within the elastic limit of the sheath. For spans sagging under gravity, the lengths are much in excess of those required for lead-sheath cable, and further experience may be required to establish convenient methods of erection to give neat and regular formation. Clamping at supports facilitates installation, but is not required on straight runs during operation.

The treatment of cable runs other than horizontal and straight is considered, the main principle being that the cable should not be restrained more than required for stable positioning, thus allowing freedom for expansion. Cleats, instead of hooks, are, therefore, called for only where there is a tendency to movement which should be prevented.

621.315.653 : 621.315.221

Improved Network Analyser

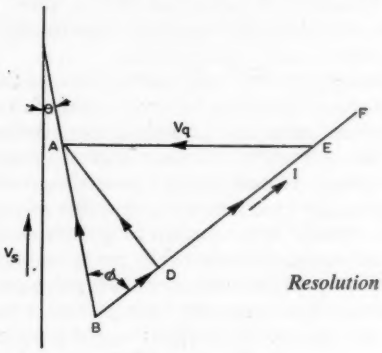
A short review of a Supply Section paper (No. 1894) entitled "The Representation of Impedances on the Resistance Network Analyser," by J. H. Field, Member. The paper was published in December, 1955, in Part A of the Proceedings.

NETWORK ANALYSERS USING ONLY RESISTORS TO REPRESENT all plant characteristics are considerably cheaper and in more general use than those which are equipped in addition with variable reactors. In consequence, a

number of methods have been developed to extend the performance of the cheaper analyser and to improve its accuracy in solving power-system problems where the power factor is not constant throughout the branches.

The paper describes a method in which the voltage across each branch of a power system is represented on the analyser by means of two voltages, one co-phasal with the current in the branch and the other a voltage injected into the branch.

In the diagram V_s is a reference vector and AB the voltage across the terminals of any branch. Conventionally, AB would be represented by a voltage BD in phase with the current I in the branch and a second voltage AD perpendicular to BD. However, by a suitable choice of resistance, the voltage BD is increased to BE and a voltage V_q = AE is injected into the branch.



Resolution of voltage

V_q is derived from a generator unique to the branch and is perpendicular to V_s.

Generators and loads are represented by suitable combinations of voltages from a 2-phase supply. In order to eliminate the expensive equipment required for orthodox metering, a method is described by which all essential measurements can be taken with a voltmeter. An appendix to the paper compares the results obtained by the method for a specific problem with a mathematical solution of the problem. 621.316.313 : 621.3.011.21

Multiple-Fault Analysis

A short review of a Supply Section paper (No. 1910) entitled "Multiple-Fault Analysis of Delta-Star Transformer Banks," by J. H. Banks, M.Sc., Graduate. The paper was published in December, 1955, in Part A of the Proceedings.

THE OCCURRENCE OF MULTIPLE FAULTS ON 3-PHASE POWER systems may give rise to abnormal over-voltage and resulting fault-current distributions, and may therefore be an important consideration when prescribing protective-gear limits. The paper briefly describes the recent method advocated by Neupauer in America for dealing with the simultaneous application of single-line-to-neutral faults on opposite sides of a delta-star transformer bank, and proceeds to compare this method with matrix methods of attack based on the work of Kron. The comparison of the two approaches reveals the inherent advantages possessed by the matrix treatment.

The classical method adapted by Neupauer involves a large amount of non-standard computation, necessitating the employment of technical staff throughout. On the other hand, a swift formulation of the problem in matrix terms enables the computation involved in the evaluations to be performed by automatic means, or alternatively, by clerical staff.

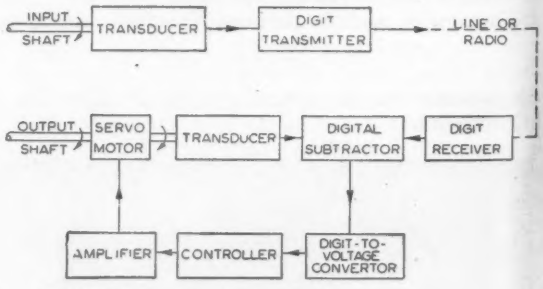
Neupauer's method cannot be readily extended to the study of simultaneous dissymmetries other than earth faults; the application of matrix techniques, however, creates no further complication in principle, and conciseness is retained.

An appendix is included showing the use of the matrix methods in conjunction with the α, β, 0 components of Clarke as an alternative treatment of transformer faults which involve extensive phase-shifts. 621.314.2

Digital Data-Transmission Systems

A short review of two Measurement and Control Section papers (Nos. 1905 and 1906) entitled "A Transducer for Digital Data-Transmission Systems," and "A Servo System for Digital Data Transmission," by R. H. Barker, B.Sc., Ph.D., Associate Member. The papers are published this month in Part B of the Proceedings.

THE TWO PAPERS DEAL WITH THE PARTICULAR PROBLEMS of digital servo systems as applied to data transmission. The digit rate is very low by computing-machine standards, being dependent primarily upon the associated communication circuit, and the emphasis throughout is upon obtaining the best performance in spite of this limitation. Fig. 1 shows the basic system. An input datum shaft is fitted with a transducer in the form of a circular scale, the position of which can be "read" photo-electrically and transmitted as electrical pulses represent-



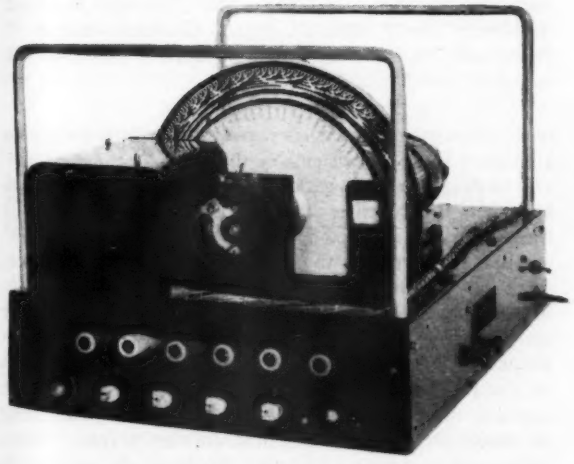
1 *A digital data-transmission system*

ing a binary number. This departure from the conventional two-shaft arrangement has the advantage that errors due to a gear train are eliminated and the accuracy depends solely upon a single precision scale.

Fig. 2 illustrates a scale pattern constructed to 10

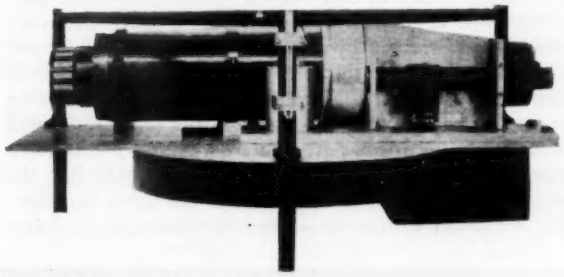
2 *Circular 10-digit binary pattern*

binary digits. In this variant of the binary pattern the least significant digit is read first, the order suited to arithmetical subtraction. There is, furthermore, a greater tolerance than is possessed by the cyclic progressive code against errors due to shaft rotation during the reading operation. A circular dividing engine has been used to manufacture, by optical projection onto photographic plates, some 14-digit scales having a reading error of less



3 *10-digit transducer used in servo experiments*

than one minute. Fig. 3 is a photograph of a 10-digit transducer, in which the scanning cathode-ray tube is mounted immediately behind the scale. The 14-digit equipment shown in Fig. 4 includes an optical system,



4 *14-digit transducer, viewed from above*

folded for compactness, giving an effective magnification of 14 times.

The unusual factors to be taken into account in designing the servo system are as follows:

Data are sampled at intervals comparable with other important time-constants.

A slow rate of transducer operation (to be synchronous with the transmission) introduces a time delay into the feedback loop.

The time taken to transmit one datum of position may be enough (perhaps a quarter of a second over a telegraph circuit) to necessitate recovery by prediction.

The data are quantized in amplitude by virtue of the digital representation.

The transducers introduce reading errors when the rate of shaft rotation is high. Although these errors could be eliminated by sufficiently rapid scanning of the pattern, they are always in the leading direction and do not necessarily detract from the dynamic performance.

Amplitude quantization and scale-reading errors together effectively constitute a source of random noise which is a function of shaft velocity except when the shaft is almost at rest, in which case there is correlation with the signal, and the system has "bang-off-bang" characteristics.* The phenomena of sampling, delayed feedback and prediction all tend to reduce stability, and

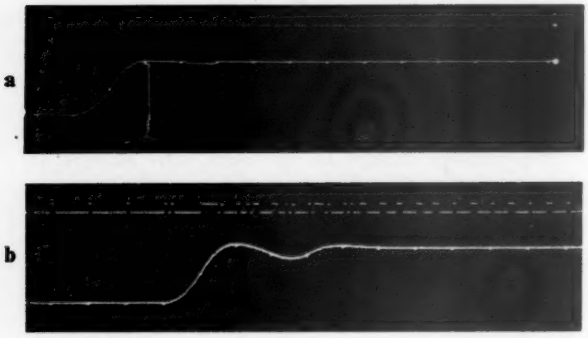
5 *Response of servo system to unit step*
(*a*) Controller output signal. (*b*) Error signal.

the theory of sampling servo-systems may be used to synthesize a control system whose characteristic equation has roots known to result, on application, in satisfactory

* i.e. the restoring force of the system is either completely zero or is constant in one or other of two directions.

performance. Such criteria as stability, overshoot, frequency response and noise magnification are studied.

Experimental work has been directed primarily at verifying the linear theory and studying the effects of quantizing noise. To this end the peculiarities of a digital system are deliberately exaggerated in order that they shall not be masked by effects common to normal servo systems. The lower trace in Fig. 5 shows the result of applying a step function to the simplest form of sampling servo system (non-digital) incorporating one data period delay in the feedback path. Only on expiry of this delay does the error become available to the controller, the output (upper trace) of which drives the servo amplifier. Fig. 6 shows the response of the equivalent digital system

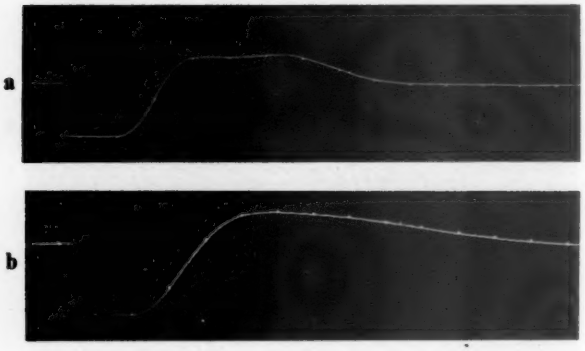


6 *Error signal response to unit step of a digital servo equivalent to that of Fig. 5*

Digital signal recorded on upper trace.
(*a*) Step as 16 units. (*b*) Step as 48 units.

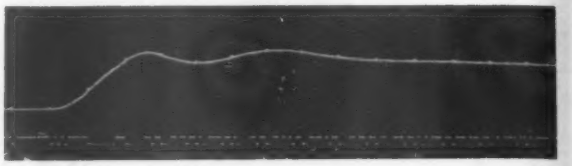
in which the delay is occupied by pattern scanning and other digital operations. In Fig. 6(*b*) the angular velocity is sufficient to introduce a scale reading error that gives rise to a subsequent "bounce."

A servo system with zero velocity-lag is capable of prediction which remains accurate so long as the angular velocity is constant. Figs. 7(*a*) and 7(*b*) are typical oscillograms in which both error and summated error are reduced practically to zero after 8 and 13 data periods respectively. The digital equivalent of the latter has the response shown in Fig. 8. In this example the scale turns



7 *Error signal response to unit step of a predicting (zero velocity-lag) servo*

(*a*) With a small amount of smoothing; (*b*) with a larger amount of smoothing.



8 *Error signal response to unit step of a digital servo equivalent to that of Fig. 7*

Step of 128 units.

through as many as 90 units (over 31°) while it is being scanned radially once. The scale-reading error is therefore large, but the normal overshoot is still building up when the "bounce" occurs and is partly neutralized by it. Under these conditions the stability of the system may actually be improved by the scale-reading error.

The general conclusion is that the servo system incorporated to regenerate the received data could be designed to make good, by prediction of the future value of the input-data function, any delay likely to be introduced by digital transmission. Prediction is necessarily accompanied by some magnification of random errors and it is thus important to smooth data as far as possible prior to initial sampling. 621.398 : 681.142 : 621–526

Transistor Amplifiers

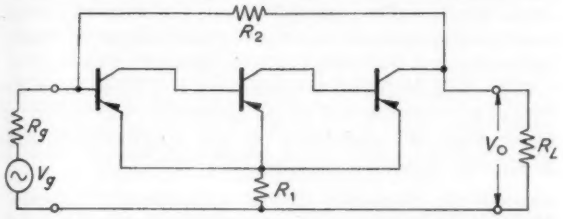
A short review of a Radio and Telecommunication Section paper (No. 1929) entitled "Broadband Transistor Feedback Amplifiers," by J. Almond, M.Sc., Graduate, and A. R. Boothroyd, Ph.D., Graduate. The paper is published this month in Part B of the Proceedings.

IT IS FREQUENTLY NECESSARY FOR THE PERFORMANCE OF amplifiers to approach closely the ideal of constant gain and perfect linear operation; this is particularly so with amplifiers of repeater type. With amplifiers utilizing transistors one way of achieving a close approximation to such properties is to apply large negative feedback. Amplifier performance may then be largely independent of considerable changes in the parameters of the transistors themselves. The paper explores the possibilities of designing amplifiers having operating gains of about 33 dB with some 30 dB of negative feedback applied, and takes as a basis an amplifier consisting of three *RC*-coupled common-emitter stages. Series, shunt and compound negative feedback are applied to this amplifier as shown schematically in the diagram

(a.c. circuit only); for series feedback R_2 is omitted, for shunt feedback R_1 is short-circuited, for compound feedback both R_1 and R_2 are present.

The exact analysis of such an amplifier circuit is very complicated owing primarily to the bilateral nature of the individual transistor stages. However, it is shown that analysis may be greatly simplified if the amount of negative feedback applied is large, when compact expressions for amplifier properties may be obtained.

When the amount of negative feedback applied to the amplifier of the diagram exceeds 19dB, measures must be taken to ensure dynamic stability of the circuit. At high frequencies self-oscillatory tendencies follow from the frequency-dependent parameters of the transistor, and one of the main objects of the paper is to show that with transistors of modest frequency range (e.g. 500kc/s) only the frequency dependence of the transistor current-gain is important in this respect, and further that in the type of amplifier considered the effects concerned are expressible by very simple analysis. It is shown that for common-emitter stages a simple minimum-phase *RC*



Application of series, shunt and compound feedback to the basic 3-stage amplifier

V_g, R_g are generator voltage and resistance; R_L is amplifier load resistance; V_o is output voltage.

approximation to the transistor current-gain characteristic gives sufficient accuracy for practical design purposes.

Examples are given of series-, shunt- and compound-feedback amplifiers having gain and negative feedback of the orders already stated, in which reasonable phase and amplitude margins of stability are secured by including phase-advancing networks in the feedback loop.

621.375.43

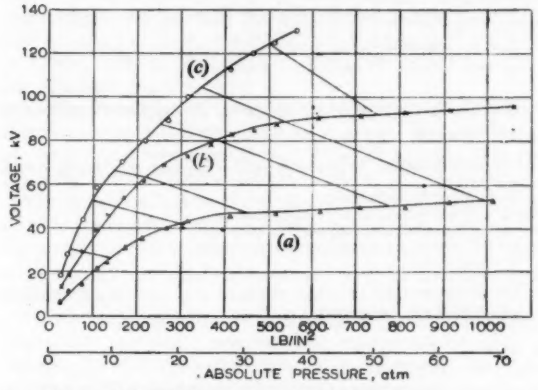
Spark-Breakdown in Compressed Gases

A short review of a Measurement and Control Section paper (No. 1922) entitled "The Electric Strength of Highly Compressed Gases," by E. Howard Cohen, Ph.D., Graduate. The paper will be published in Part A of the Proceedings.

GASES UNDER PRESSURE ARE NOW USED FOR THE ELECTRICAL insulation of transformers, cables, switchgear, rectifier sets, condensers and Van de Graaff generators.

Although many measurements have previously been made of the electric strength of compressed gases, no direct comparisons have been made between the strengths of various gases over an extended pressure range, and the author has therefore carried out a study of this nature on air, nitrogen, carbon dioxide, sulphur hexafluoride, Arcton 6 (CCl_2F_2) and other fluoromethanes and on some mixtures of these gases over a pressure range of 1 to 75atm. Direct voltages up to 130kV and a uniform field gap were used.

Fig. 1 shows that there is a limit to the effectiveness of



1 *The spark-breakdown strength of nitrogen*

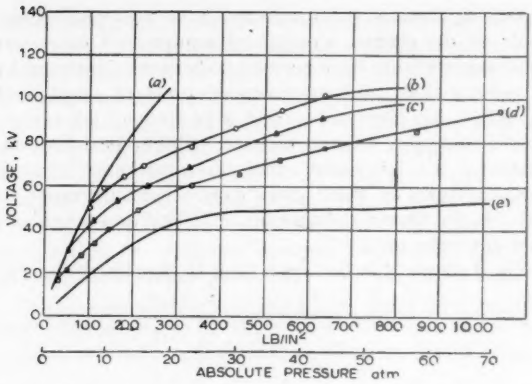
Electrode material: bright mild steel. Gap lengths: (*a*) 1mm, (*b*) 2mm, (*c*) 3mm. Curves for which individual points are not shown are for constant values of the product of gas pressure and gap length.

adding nitrogen (containing less than 10 parts per million oxygen) in an electrode gap in order to increase the electric strength of the gap. There is a marked saturation effect, for both the 1mm and 2mm gaps, when an electric field of strength 450kV/cm is reached. At this point an electrode mechanism becomes dominant in the breakdown process and the gap strength becomes almost independent of increased gas pressure. The failure of Paschen's law at high gas pressure is also evident.

The addition of even a small proportion of an electronegative gas like SF_6 is seen from Fig. 2 to result in a marked increase in the strength of the gap. It is also seen that although the initial effect of adding electronegative molecules is considerable, further increase of the partial pressure of the electronegative gas gives decreasing returns. This again suggests that an electrode mechanism which is highly dependent on the electrode voltage gradient soon overcomes the effect of electronegative molecules in quenching discharges in the gap.

Fig. 3 confirms the importance of electrode processes in the breakdown mechanism. However, the nature of the insulating gas remains more important than the electrode material in determining the strength of the gap.

Fig. 4 provides an interesting insight into the changes taking place in the breakdown mechanism as the gas

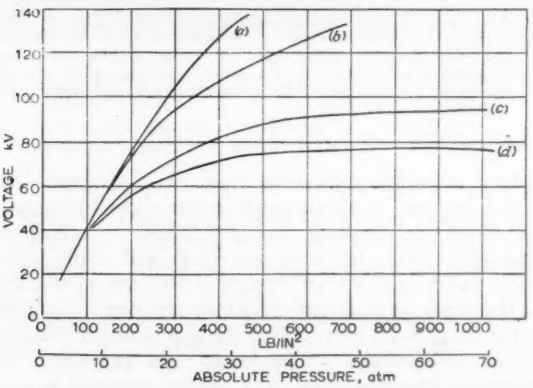


2 *The electric strengths of mixtures of sulphur hexafluoride and nitrogen*

Electrode material: bright mild steel. Constant gap length: 1 mm.

(*a*) Sulphur hexafluoride.
(*b*) 7 atmospheres sulphur hexafluoride.
(*c*) 3·5 atmospheres sulphur hexafluoride.
(*d*) 0·7 atmosphere sulphur hexafluoride.
(*e*) Nitrogen.

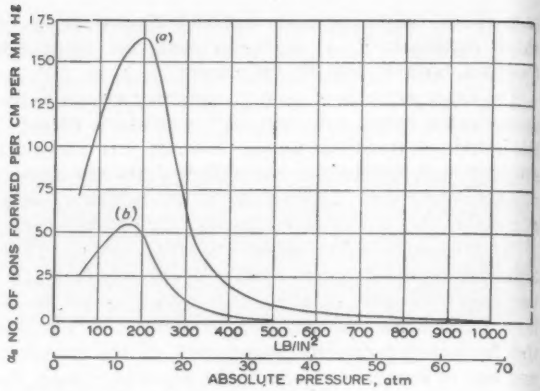
The pressures refer to initial pressures of sulphur hexafluoride, to which nitrogen was added.



3 *Summary of results with air and nitrogen and different electrode materials*

Gap length, 2 mm.
(*a*) Air; bright-mild-steel electrodes.
(*b*) Air; aluminium electrodes.
(*c*) Nitrogen: bright-mild-steel electrodes.
(*d*) Nitrogen; aluminium electrodes.

pressure increases. The initial linear increase of α_s (the first Townsend ionization coefficient corresponding to the spark-breakdown voltage) with pressure corresponds to the condition when the breakdown voltage is proportional to the gap length. Such a linear increase is then predicted by Paschen's Law. At higher gas pressures not only does Paschen's Law fail but the electron avalanche which will develop in the gap from a single initiating electron is of puny proportions—an observation which



4 *The variation of α_s with pressure*

Electrode material: bright mild steel. Gap length: 1 mm.
(*a*) Air. (*b*) Nitrogen.

has been made before by both Boulloud* and Young.† Thus neither the streamer theory of breakdown at atmospheric pressure nor the Townsend type of breakdown explains the breakdown at high gas pressure.

We conclude that the breakdown is a function of the emission characteristics of the electrodes, the density of electronegative molecules in the gap, and the probability of electron attachment to these molecules.

* BOULLOUD, A.: "Amorçage de l'étincelle électrique dans les gaz comprimés," *Annales de Physique*, 1953, **8**, p. 909.

† YOUNG, D. R.: "Electric Breakdown in CO_2 from Low Pressures to the Liquid State," *Journal of Applied Physics*, 1950, **21**, p. 222.

621.315.618 : 621.3.015.5

Design of H.F. D.F. Systems

A synopsis of a Radio Section paper (No. 1960) entitled "On the Theoretical Design of Direction-Finding Systems for High Frequencies," by W. C. Bain, M.A., B.Sc., Ph.D. The paper is published this month in Part B of the Proceedings.

THE PROBLEM OF FINDING THE BEARING OF A DISTANT H.F. transmitter in conditions of wave interference is examined for the simplified case of non-interacting aerials on a plane earth and with no pick-up of horizontally polarized radiation. Two methods of approach are considered—solution of the field equations for a number of incident plane waves from a knowledge of the field at the aerials, and the fitting of rectilinear constant-phase lines to observed values by a "least squares" process. It is shown that the cyclical system of Earp and Godfrey is a "least squares" system of the latter type. Systems of the "Wullenwever" kind bear a close resemblance to a "least squares" system with weighting according to the signal amplitude at each aerial, but they operate with sinusoidal instead of linear functions of phase.

621.396.93

OBITUARY

HAROLD BENTHAM

Harold Bentham, who died on the 5th July, 1955, was born on the 21st March, 1876. The son of a Yorkshire mining engineer he first studied electrical subjects at evening classes in Sheffield after his shift in the pit. Having obtained six years' industrial experience in generation with J. and J. Charlesworth and Co., he joined the electricity supply industry on taking up an appointment as Assistant Engineer with Brighton Corporation. From there he went in 1902 to the newly authorized Birkdale District Electric Supply Co., supervising the construction of their generating station and laying out the distribution system.

In 1912 he became Station Engineer at the Smethwick generating station, at that time one of the largest in the country. He later joined the head office staff of the Shropshire, Worcestershire and Staffordshire Electric Power Co. as Deputy Chief and Power Station Engineer, and in this capacity did much of the early work on the Stourport generating station, and explored the possibilities of hydro generation on the river Severn. Thereafter, until nationalization, he was a director and Advisory Engineer to the Lewes, Merthyr, Sheerness, Birkdale and Weston-super-Mare electricity supply companies in the British Electric Traction group, also becoming Managing Director and Chief Engineer, from 1940, of the Lothian, Musselburgh, Boston, Colne Valley and Northwood electricity supply companies. He retired in 1949.

He contributed most assiduously throughout his career to the public life of the industry. He was a member of the Council of the Incorporated Association of Electric Power Companies and of the Provincial Electric Supply Association, and represented both bodies on numerous committees. He had a special interest in rural electrification, and in retail tariffs and served on various committees set up by the Electricity Commission on these subjects. In this work he made up his mind which was the right line to take on the subject under discussion, and gave his views forthrightly, but although tenacious in negotiations, he was always able to compromise to reach a settlement on fair terms.

He was a quiet man of simple tastes and had no real interest outside his work and his family. He married in 1902 and his wife, Mrs. A. Bentham, who survives him, was an early member of the Electrical Association for Women, and became Chairman of the Association. Mr. Bentham was able to draw on her experience as a progressive domestic consumer in his work for the wider domestic use of electricity. He is also survived by one of his two sons, for whom he was willing to make any personal sacrifice.

He joined The Institution as an Associate in 1898 and was elected an Associate Member in 1902 and a Member in 1941.

J. C. J. D.

WALTER HENRY COOKE

Walter Henry Cooke, who died on the 22nd July, 1955, was born on the 6th March, 1870. He was educated at the Royal Grammar School, Henley-on-Thames, and by private tutor, and received practical training with W. Mackie and Co., at London. In 1889 he was appointed Electrical Engineer with the London and South Western Railway Co. at Southampton, where he was engaged on the installation of electric lighting on Channel boats. He was promoted to Resident Electrical Engineer in charge of the electrical installations at Southampton Docks. He returned to London in 1900 as Assistant Electrical Engineer in the firm of Albion T. Snell and Partners, assisting them in the completion of an electricity supply scheme at Luton. He moved to the latter town in 1901 to take up an appointment as Chief Engineer and Manager of Luton Corporation Electricity Supply Undertaking, with whom he spent the rest of his professional life. He was responsible for the installation and maintenance of electrical equipment of a total capacity of 17 000 kW; Luton electricity was indeed Mr. Cooke's prerogative.

Like other engineers of his generation, he carried out very definite and uphill battles and he was very proud to be one of the original members of the "Point 5" organization. This pride lay in the ability to sell electricity at ½d. per unit.

The area supplied by the Borough of Luton was originally only 5 sq. miles but Mr. Cooke was instrumental in extending the supply so that in the year 1927 the area was 200 sq. miles, covering the surrounding rural districts, in which he had a definite interest.

He also was one of those who foresaw the wisdom of interconnection between neighbouring undertakings, and the occasion is well remembered when he witnessed the Luton supply coupled to that of a large adjacent power company.

Mr. Cooke joined The Institution as an Associate in 1896 and was elected an Associate Member in 1899 and a Member in 1931.

W. N. C. C.

MANLEY FARRER

Manley Farrer, who died on the 13th July, 1955, was born on the 7th December, 1877. He was educated at University College School, London, and subsequently attended a course in electrical engineering at University College. He completed his education by evening studies at Birmingham Technical School, while gaining practical experience as an apprentice to the firm of Belliss and Morcom at Birmingham. In 1900 he obtained a post as Junior and Shift Engineer at the Westminster Electric Supply Corporation, and in 1902 he joined the Twickenham and Teddington Electric Supply Co. as Chief Assistant Engineer. In 1904 he was transferred to the Ramsgate and District Electric Supply Co., but returned to the Twickenham and Teddington Electric Supply Co. in 1908, as Engineer and Manager. The company was taken over by the London and Home Counties Joint Electricity Authority in 1931 and Mr. Farrer was appointed Senior Area Engineer and Manager, a post which he retained until he retired in 1943.

In the early days he was responsible for installing a 2 500 volt d.c. transmission line in the Thames valley. Later he carried out the change from d.c. to a.c. transmission in the areas of Twickenham, Teddington, Hampton, Hampton Wick, Molesey, Esher, Weybridge, Surbiton and Ham.

Holidays spent climbing in Switzerland as a young man undoubtedly contributed to the agility with which he climbed the 120 ft stack at the Twickenham works to inspect repairs to the brickwork and lightning conductor.

Manley Farrer was a quiet man but his mind was alert and quick to clarify involved discussion and to summarize the pertinent points. By his kindly disposition he endeared

himself to all with whom he came in contact, and he was affectionately known as "M. F." by the workmen and office staff. A keen sportsman, he acted as one of the judges each Sports Day. During the First World War he was a special constable in the Twickenham area.

To the older members of the Joint Electricity Authority and its forerunner his cheerful personality and sound advice will be sadly missed.

Mr. Farrer joined The Institution as an Associate Member in 1905 and was elected a Member in 1912. F. C. L.

REGINALD FRANCIS LEGGE

Reginald Francis Legge, C.B.E., D.S.O., who died on the 24th August, 1955, as the result of a motor accident in France, was born on the 22nd September, 1873. Educated at St. Paul's School, Kensington, and the Royal Military College, Sandhurst, he entered the regular army and served with distinction, rising to the rank of Brigadier-General.

He became associated late in life with the electricity supply industry when, in 1925, he was appointed Treasury Director of both the North Wales Power Co. and the Electricity Distribution Company of North Wales and District, under the Trades Facilities Act. As such he became a member of the Incorporated Association of Electric Power Companies and quickly proved to be a valuable member of this important body.

In 1929 he was made Director and General Manager of the British Power and Light Corporation, controlling the North Wales Power Co. and six small and vigorous undertakings in various parts of the country. For 10 years he edited a quarterly magazine called *Helios* dealing with distribution matters, which had many contributions from engineers of distinction. He was also a member of the British Electrical Development Association for some years, serving as Vice-Chairman in 1936–37 and Chairman in 1937–38. General Legge made many friends in the industry and was actively engaged therein until nationalization took place.

He was elected a Companion of The Institution in 1932 and was a Member of Council from 1934 to 1937. J. M. D.

FRANK WALTER SHILSTONE

Frank Walter Shilstone, who died on the 12th October, 1955, was born on the 1st May, 1892, and was educated at St. Joseph's College, North Point, Darjeeling, from 1906 to 1910. He then came to England and took a course in Civil and Mechanical Engineering at London University, where he obtained the Associateship of the City and Guilds Institute.

During the 1914–18 War he was commissioned as a 2nd Lieutenant in the Royal Garrison Artillery and served both at home and in France as a Trench Mortar Officer. He was wounded and invalided home and subsequently held appointments in 1918 and 1919 with the Ministry of Munitions in their Trench Warfare Design Department.

After spending three months under Mr. Gaze, the Chief Engineer of the Central Electric Supply Co., at Grove Road power station, he joined the firm of Kennedy and Donkin, Consulting Engineers, as Assistant Engineer, and rose to the position of head of their Industrial Department.

One of his first jobs on joining the firm was to help in supervising the erection of the new power station at Portobello. After that he was engaged on the railway electrification work which the firm were at that time doing for the London and South Western Railway and later the London and South Eastern Railway. He was also concerned with the installation of generating plant in the power station of Michael Nairn and Co. of Kirkcaldy, linoleum manufacturers. After his return from Kirkcaldy to London in 1928 he was employed until 1930 on work for the Central Scotland and North West England Divisions of the Central Electricity Board.

From 1930 to 1935, during which time he held the position of one of the firm's Chief Engineers, he was engaged on design and contract work for the South West England and South Wales Divisions of the Central Electricity Board, which involved responsibility for contracts to a value of £3 500 000.

In 1935 he left Kennedy and Donkin to become Managing Director and Chief Engineer with the Town and Factories Development Co., where he promoted the work of town planning with special reference to the generation and utilization of heat and electricity. He prepared plans for industrial estate schemes including a carbide factory and a 30 000 kW power station.

He rejoined Kennedy and Donkin in February, 1940, his first job being to assist in the electrical equipment of an underground aircraft shadow-factory at Corsham, near Bath. He returned to the Head Office in 1943 and took a large part in the design of the new back-pressure generating plant for Jas. Williamson and Son, at Lancaster. Thereafter, he was occupied on similar work until his sudden death.

Mr. Shilstone joined The Institution as an Associate Member in 1933 and was elected a Member in 1938. B. D.

CHARLES WHILLIS

Charles Whillis, who died in July, 1954, was born on the 28th February, 1874. He was educated at Westmorland Road School, and at Smart's Tutorial College, Newcastle upon Tyne, and in 1889 entered the service of Newcastle upon Tyne Post Office as a telegraphist. While working he attended evening classes at Rutherford College and Armstrong College for six years, obtaining the City and Guilds Institute prizes in Telegraphy and Telephony, the City and Guilds Institute Full Technological Certificate, and a first-class pass and prize in the Junior Electrical Engineering examination of Durham College.

In those days many engineers in the Post Office were recruited from telegraphists and in 1896 Mr. Whillis became a clerk in the Engineering Department at Newcastle. Three years later he was appointed Sub-Engineer in the office of the Superintending Engineer, Mr. A. W. Heaviside, brother of Oliver Heaviside.

In 1902 he was transferred to London for seven years as an Engineer Second Class and was engaged on the construction and maintenance of all classes of telegraph and telephone plant. He was then promoted to the rank of Executive Engineer at Carlisle, and in 1918 was transferred to Newcastle upon Tyne. Eight years later he rose to the rank of Assistant Staff Engineer, and four years after that to Superintending Engineer for West Scotland, where he remained until his retirement in 1934. During his term of office at Glasgow he was responsible for a number of important technical developments including the conversion of the Glasgow telegraph system to teleprinter operation and the reconstruction of the Glasgow trunk exchange to provide for "on demand" working.

Mr. Whillis was a man of genial and kindly disposition and was always ready to help a younger colleague with information and advice.

He joined The Institution as an Associate Member in 1910 and was elected a Member in 1921. A. J. G.

HARRY EDWARD YERBURY

Harry Edward Yerbury, who died on the 13th July, 1955, was born on the 30th January, 1871.

From 1896 to 1899 he was Chief Assistant Engineer at the Bristol Carriage and Tramway Co., engaged on the construction and maintenance of electric tramways. He then took up a similar appointment with the Sheffield City Tramways Department, and in 1903 was promoted to Chief Electrical Engineer.

In 1914, when the Corporation Electricity Undertaking took over the responsibility of generating electricity for the city tramways, Mr. Yerbury was appointed Deputy General Manager and Engineer of the Sheffield Electricity Undertaking. He remained in that position until 1929, when he retired.

Mr. Yerbury was a pioneer motorist and is thought to have owned the first steam-driven motor-car in Sheffield. He was also one of the founders of the Sheffield Wireless Society, which he served for two years as President. He was very well liked and was a great asset at social gatherings.

Mr. Yerbury joined The Institution as an Associate in 1897, was elected an Associate Member in 1899 and a Member in 1908. He served on the Leeds Local Section Committee from 1904 to 1907, was Vice-Chairman of the Section in 1907–8 and Chairman in 1908–9. While he was Past-Chairman (from 1909 to 1912) the Section became the Yorkshire Local Section and Mr. Yerbury continued to serve on the Committee of this Section from 1912 to 1914. He was later Vice-Chairman of the Sheffield Sub-Centre from 1925 to 1927 and Chairman in 1927–28, and served on the Committee of the Sub-Centre from 1928 to 1931. He contributed three papers to the *Journal*: "Equitable Charges for Tramway Supply," published in 1910, "Effect of Air and Water on Materials," published in the Supplement to the *Journal*, 1919, and "Power Factor: Its Technical and Commercial Aspects," published in 1923.

He was also a Member of The Institution of Civil Engineers and a Member of The Institution of Mechanical Engineers.

J. A. W.

CORRESPONDENCE

THE THEORY OF DIMENSIONS

From D. A. BELL, M.A., PH.D., MEMBER

As Dr. L. Hartshorn said in the *Journal* for October, 1955, the system of "dimensions" is a convention; and before modifying a convention one should have a clear view of its purpose.

Hitherto the system of dimensions has served the two purposes of indicating what standard units must be available for the specification and measurement of a physical quantity and what will be the numerical effect of a homogeneous change of scale of one of the physical factors involved, but dimensions have not been used to show *how to make the measurement*. The introduction of three components of length (L. Young, L. H. A. Carr) purports to do the latter: e.g. it distinguishes *torque* from *work* by considering the nature of the individual measurements of length involved in each. If L_x, L_y, L_z, are thought of as separate entities, it is at least advisable to treat them as vectors. Work is scalar, involving the scalar product of L_x by itself, but torque results from a vector product of two lengths which are at right angles, and is represented by a vector in the direction of the axis of rotation.

$$[W] = [ML^2T^{-2}]$$
$$[T] = [ML_r \times L_pT^{-2}]$$

Since the notation L_x is commonly used for the magnitude of the x component of a vector L, it is preferable to refer directly to the radial and peripheral nature of the two length vectors. In this way one can indicate how the measurement is to be performed, but I do not myself advocate this extension of the use of dimensions.

Dr. Bell is in the Electrical Engineering Department, University of Birmingham.

From F. T. CHAPMAN, C.B.E., D.SC.(ENG.), B.SC., MEMBER

In his letter published in the *Journal* for October, 1955, Mr. L. Young draws attention to the advantage of using a dimensional constant for solid angle. I think he has made a slip, however, in saying that the unit of solid angle in a rationalized system is the steradian and in an unrationalized system, the sphere; the reverse is the case. The S in his equations is a measure number. It is therefore inversely proportional to the size of the unit of solid angle in the system of units employed and its value is 1 for the large unit, the sphere, and 4π for the small one, the steradian.

Dr. Chapman is a consultant.

From H. W. HECKSTALL-SMITH, M.A.

The argument of Mr. L. H. A. Carr's letter in the *Journal* for November, 1955, that the directional properties of the dimension of length should be taken into account when this dimension corresponds to a vectorial, not to a scalar, quantity, applies to *conductivity* and to *resistivity*. The unit-names "mho/metre" and "ohm-metre," as given in The Institution's pamphlet on symbols and abbreviations* are the result of illegitimate cancelling of mutually perpendicular lengths if Mr. Carr's argument is accepted. They are in any case needlessly confusing to students, who can grasp the relevant formulae easily if they visualize each of these quantities as measured between opposite faces of a unit cube. Would it not be better to call the units "mho per metre cube" and "ohm per metre cube" respectively?

* "Symbols and Abbreviations in common use in National Certificate Courses in Electrical Engineering" (Institution of Electrical Engineers, London, 1955), pp. 3–4.

Mr. Heckstall-Smith was formerly Science Tutor of Stowe School.

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A list of papers published in the January issue of Part B of the *Proceedings* appears under "Contents of the Current Issues of the *Proceedings*" on page 82, and the serial number of each paper and the month of publication of a review in the *Journal* are included. Synopses of both monographs and papers which will be published separately before the next issue of the *Journal* appear below, and unless otherwise stated, their date of publication is the same as this issue of the *Journal*. The monographs will be republished in Part C of the *Proceedings*, and the relevant Part for the republication of a paper is given after the serial number of the paper.

MONOGRAPHS

Relative Dynamic Stability of Large Synchronous Generators

MONOGRAPH No. 159 S

H. K. MESSERLE, M.Eng.Sc., B.E.E.

The steady-state stability limit of a synchronous machine can be modified considerably by controlling field excitation and prime-mover torque by means of regulators and governors. In the paper the effects of the individual alternator parameters and controller constants on the dynamic stability limit (i.e. the steady-state limit of a controlled alternator) are investigated, and optimum operating conditions for various types of regulators and governors are established.

The investigation covers a general comparison of the relative dynamic stability of the common types of large alternators. In addition, the variation in dynamic stability with a change in output rating is discussed.

An Experimental Study of Intensity Spectra after Half-Wave Rectification of Signals in Noise

MONOGRAPH No. 160 R

G. E. FELLOWS and D. MIDDLETON

Measurement has been made of the spectral intensity of the harmonic zones which exist at the output of a non-linear device fed by narrow-band noise and an unmodulated carrier. The spectral shape, the maximum spectral intensity, and the carrier component in each of the first six harmonic zones have been determined both theoretically and experimentally for a half-wave νth-law rectifier with $\nu = 1/2$, 1 and 2, for a wide range of input carrier/noise ratios.

The measuring equipment is discussed in the paper, the theoretical and experimental results are compared, and a number of computed results of practical interest are presented.

The Inductance of Iron-Cored Coils

MONOGRAPH No. 161 S

P. HAMMOND, M.A.

The magnetic field in the neighbourhood of coils threaded through holes in iron cylinders is calculated. The results are relevant to the estimation of the self-inductance of rotating machines and transformers and form the basis for an examination of the soundness of approximate formulae used in the design of such apparatus.

An Approximate Method for Finding the "Best Linear Servo Mechanisms"

MONOGRAPH No. 162 M

H. H. ROSENBROCK, B.Sc.(Eng.), Ph.D.

Wiener has given an explicit solution for the servo mechanism which minimizes the r.m.s. error when the system is following a signal contaminated with noise. The paper describes an elementary graphical method for evaluating Wiener's results, and makes use of a pair of transparent cursors which have already been described. An example is given, from which it appears that the accuracy of the method may be sufficient for engineering purposes.

An intermediate result of the graphical method gives the minimum phase corresponding to a given attenuation characteristic.

Analysis of Linear *n*-Port Networks

MONOGRAPH No. 163 R

I. CEDERBAUM

Some properties of a general, non-reciprocal, linear network with n accessible terminal pairs (n-port) are investigated. By using a symbolic notation a unique expression for all network functions is derived. This expression can be obtained in terms of the sub-determinants of the open-circuit impedance or the short-circuit admittance matrix of the n-port and is applicable with any combination of open- or short-circuits at the network ports. Since all network functions, with such terminations of the n-port, may be expressed in terms of sub-determinants of one and the same matrix, numerous relations between them may be established. Some examples illustrate the application of this method.

The Eddy-Current Anomaly in Electrical Sheet Steel

MONOGRAPH No. 164 M

H. ASPDEN, Ph.D., B.Sc., Wh.Sc.

A theory which accounts for the well-known discrepancy between eddy-current losses in electrical sheet steels and the experimentally observed values is presented. The anomaly is shown to be due partly to the magnetic inhomogeneity arising from ferromagnetic domain structure and partly to a time-lag effect caused by the finite speed of domain boundary move-

ments. A new experimental approach to the study of the eddy-current anomaly is described. This involves the use of a method of measuring the anomaly factor as it applies instantaneously at a point in a magnetization cycle.

Magnetic Time-Lag Effects in Solid Steel Cores

MONOGRAPH NO. 165 M

H. ASPDEN, Ph.D., B.Sc., Wh.Sc.

The discrepancy between the theoretical eddy-current effects and the actual eddy-current effects in thick steel cores is investigated. By using thick cores the magnetic inhomogeneity arising from ferromagnetic domain configuration becomes of little consequence and the discrepancy may be attributed to an intrinsic time-lag effect in the magnetization process. This time-lag is measured and explained in terms of a localized eddy-current action associated with the dissipation of hysteresis loss. It was found that the time-lag depended upon frequency and was less important at high frequencies.

PAPERS

D.C. Circuit Interruption and Arc Characteristics at Low Air Pressures

PAPER NO. 1935 U; PART A

A. H. M. ARNOLD, D.Eng., Ph.D., and L. H. FORD, M.Sc.(Eng.)

This report summarizes work carried out by the National Physical Laboratory at the request of the Ministry of Supply. Measurements have been made of the voltage and current in d.c. arcs over a range of air pressures using silver, copper and tungsten electrodes. The investigation has shown that, although the arc characteristic at low pressures is less favourable for breaking large currents than it is at atmospheric pressure, comparable switch performance may usually be obtained either by an increase of gap length, or by an increase in the number of series breaks. Simple empirical relationships for the arc characteristics based on the experimental data obtained are given for silver and tungsten electrodes. Tests on the interrupting capacity of switches gave results which were in reasonable agreement with predictions made from these empirical formulae.

Applications of the 3 : 1 Pole-Changing Motor

PAPER NO. 2010 U; PART A

T. H. BARTON, Ph.D., O. I. BUTLER, M.Sc., and H. STERLING, B.Sc.

The paper will be published on February 6th.

Besides the obvious application of providing two separate and economical running speeds, the application of the 3 : 1 pole-changing motor to obtain controlled starting, stopping and reversing of industrial drives is considered in some detail. For the latter types of drive an investigation is made of the energy loss involved, and a comparison is made with other methods of control.

The author shows that various asymmetrical connections of the primary winding for the larger pole-number can provide useful characteristics for both squirrel-cage and slip-ring machines, and, in general, a 2-phase connection of the primary winding for the larger pole-number is likely to be more satisfactory than a 3-phase connection.

Age and the Incidence of Fires in Electrical Installations

PAPER NO. 1938 U; PART A

L. GOSLAND, B.Sc.

The paper reviews data on the occurrence of fires due to defects in fixed electrical installations amongst a population of about 2·5 million consumers over the years 1951–53 inclusive. The correlation between age of installation and the incidence of fires is examined, and it is shown that for installations more than fifteen years old the incidence of fires is roughly proportional to the age of installation. There is no clear indication of any maximum safe life. Installations less than fifteen years old are considered as a separate class, being subject to innovations in housing construction and installation practice. Incomplete data on the types of equipment revealed as defective and on the nature of the defects are reviewed. There is no clear indication that any one type of equipment is particularly subject to the effects of age. The most frequent primary cause is defective wiring, and the most frequent secondary cause fortuitous contact between wiring or earth-continuity conductors and composition gas-pipes. Apart from the latter, there seems no single type of defect the elimination of which could lead to an outstanding reduction in the incidence of fires.

A Transistor Digital Computer

PAPER NO. 1964 M; PART B

E. H. COOKE-YARBOROUGH, M.A., R. C. M. BARNES, B.Sc.(Eng.), J. STEPHEN, Ph.D., and G. A. HOWELLS

The paper describes a small digital computer which has a magnetic-drum store and uses some 330 transistors as the only active circuit elements.

The logical design is unusual, involving the interleaving of the digits of numbers stored on the drum; this permits 3-address operation, all three addresses being on the drum, and calls for relatively little storage capacity external to the drum. Although the time taken to perform individual operations is rather long, this is compensated for by the fact that the design readily permits a close approach to an optimum programme.

Electrical Machines for Aircraft

PAPER NO. 1971 U; PART A

B. ADKINS, M.A., W. PHILIPP, B.Sc., and A. HOSSLE, B.Sc.(Eng.)

The electrical machines used in aircraft differ greatly from normal industrial machines because they must have the lowest possible weight and bulk, but must be capable of operating over a wide range of ambient temperature and air pressure at varying altitudes. Special materials and methods of construction are therefore used in order to permit a high operating temperature and a high specific loading at a high speed.

Machines both for direct current and alternating current are considered and are classified as generators, motors and converting machines. The well-established engine-driven blast-cooled d.c. generator receives a good deal of attention. The use of high-temperature insulation, brazed connections, impregnated brushes, high-permeability magnetic materials and other special features are discussed in some detail. D.C. motors, while offering more variety, give rise to fewer difficult design problems.

Alternating-current generators may run over a wide speed range, as in many present-day installations in which most of

the output is rectified in order to provide a d.c. supply, or they may be driven at constant speed from a variable-ratio gear coupled to the main engine or from a separate turbine. The insulation and constructional problems are similar to those of the d.c. generator. A.C. motors, inverters and rotary transformers introduce their own problems in relation to starting, regulation and other requirements.

The paper attempts to give a general picture of the present state of development and to indicate the ways in which further advances are likely to be made in the future.

The Penetration of Surge Voltages through a Transformer coupled to an Alternator

PAPER NO. 1997 S; PART A

B. C. ROBINSON, Ph.D., M.Sc.

The paper will be published on February 13th.

Most modern transmission systems operate at 66 kV or higher voltages and are supplied from alternators whose voltage is stepped up by transformers. When considering the effect of transmission-line lightning surges on a power-station one must necessarily treat the transformer and alternator as a single unit.

After a brief analysis of the phenomena likely to be produced when an impulse voltage is applied to a transformer coupled to an alternator, the results are confirmed by tests on three such units. These show that the principal transfer of voltage through a transformer is due to magnetic coupling between windings, and causes an oscillatory voltage to be superimposed on the surge voltage in the l.v. winding of the transformer. Approximate empirical methods are given to calculate the l.v. winding voltages from the various circuit parameters. The results obtained are compared with experimental ones.

Since in practice the transformer and alternators are excited at power frequencies whenever a surge is likely to reach the windings, it is necessary to allow for this when estimating the voltages which may occur at the alternator terminals. On the assumption that the surge protection for the unit consists of a rod-gap or other voltage-limiting device at the transformer h.v. terminals, an analysis is made with a view to ascertaining the maximum voltage which may occur at the alternator terminals.

The Potentialities of Railway Electrification at the Standard Frequency

PAPER NO. 1998 U; PART A

E. L. E. WHEATCROFT, M.A., and H. H. C. BARTON, B.A.

The paper will be published on January 23rd.

The paper discusses the technical and economic aspects of railway electrification using alternating current at the standard frequency. The authors accept that, for suburban traffic, d.c. electrification provides a satisfactory operating, technical and economic answer, but they seek to establish that for new main-line projects the 50 c/s system is cheaper than other systems and may be installed without technical difficulty. For some railways it becomes economically superior to Diesel traction.

The Propagation of Surge Voltages through Turbo-Alternators with Concentric-Conductor-Type Windings

PAPER NO. 2018 S; PART A

B. C. ROBINSON, Ph.D., M.Sc.

The paper will be published on February 13th.

The study of the propagation of surge voltages in conventional alternator windings is modified to apply to the concentric-conductor type of winding used for some machines having a terminal voltage of 22 or 33 kV. The theoretical analysis shows that the wave entering the winding at the machine terminal sets up series of travelling waves between each pair of adjacent conductors in the bars. The waves in the outer conductors travel slowest, owing to the presence of the iron core which forms the return circuit. The waves are reflected and refracted at the junction of the various sections of the winding.

Test results on a typical machine are given, and the initial voltage distribution is explained in terms of the theoretical travelling waves. Measured values for the winding surge impedance are compared with those deduced theoretically.

TECHNICAL PUBLICATIONS

THE BEAMA CATALOGUE 1955–56

The third (1955–56) edition of the BEAMA catalogue has recently been published. This large book, containing more than 1 000 pages, serves as a buyer's guide to the products and services of Britain's electrical manufacturing industry. There are three sections, which deal with (i) electrical power plant; (ii) electrical equipment in industry, transport and communications; and (iii) domestic and commercial electrical appliances, lighting equipment, etc. To help oversea buyers a five-language glossary of technical terms is included. The catalogue contains a classified section, giving the names of manufacturers of electrical equipment, under some 1 200 classified headings.

The President of the Board of Trade has written a foreword for the catalogue, which also contains a section setting out the history and constitution of the British Electrical and Allied Manufacturers' Association, with some notes on its present-day activities, including those concerned with exports.

E.R.A. REPORTS

The Secretary has been asked to draw attention to the undermentioned E.R.A. Reports. Copies can be obtained from the British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. The price of each report is given, and unless otherwise stated, the cost of postage on a report is 3d.

G/T296. "EFFECT OF ARCING ON THE AIR FLOW THROUGH THE NOZZLE OF A GAS BLAST CIRCUIT BREAKER (SUMMARIZING REPORT)." BY A. A. HUDSON. 21s. (POSTAGE 5D.).

A summary of investigations into the influence of the arc upon the air flow in the nozzle electrode of an axial-flow-type air-blast circuit-breaker. The mass flow of air through the nozzle during arcing and the static pressure at three points within it have been measured.

G/T297. "The Effect of Enclosure on the Temperature Rise of Fuses." By H. W. Baxter. 10s. 6d.

The object of this investigation was to devise a simple method of estimating the temperature rise of fuses when mounted in enclosures.

It is a simple matter to measure the temperature rise of a fuse, but there are so many ways of mounting fuses that it would be very tedious, even impracticable, to measure the temperature rise under all conditions of service. Because of this, it was thought that the best method of attacking the problem was to ascertain how heat is dissipated from a fuse, since it might then be possible to evolve an empirical method of estimating the temperature rise under a wide range of conditions.

L/T287. "Electrode Processes in Spark Discharges." By R. Craig. 12s. 6d.

The effect of different electrode materials on the voltage/gap-length characteristics of 6 sec 100 amp rectangular-current-pulse spark discharges in hydrogen, air and argon has been investigated.

L/T316. "Polarization of Dielectrics by Slow Particles." Part III. By H. Pelzer. 7s. 6d. (postage 4d.).

An expression for the dissipated energy, taking into account electronic as well as ionic polarizability, is derived from an expression due to Fröhlich and Platzman, by a short method made possible through a delta function relation of Gross and Pelzer. The expression for electric energy and other relations are derived phenomenologically from the dispersion law for the permittivity.

L/T317. "On the Thermal Excitation of Trapped Electrons in Ionic Solids." By J. H. Simpson. 12s. 6d.

The ground state energy of an electron trapped at a defect of the interstitial or substitutional type in an ionic crystal is determined by a variational method in which the interaction between electron and lattice vibrations is treated on a dynamic basis. The results are compared with static calculations using a self-consistent method, and it is shown that for certain ranges of the low- and high-frequency dielectric constants an appreciable difference in energy may occur.

L/T318. "Gas Temperature in Argon Spark Channels." By R. D. Craig. 6s.

The purpose of this report is to give preliminary data obtained in trial experiments to determine spark-channel gas temperatures.

L/T322. "Plasma Oscillations and Energy Loss of Charged Particles in Solids." By H. Fröhlich and H. Pelzer. 3s.

Recently Bohm and Pines have demonstrated that the long-range Coulomb interaction of the conduction electrons in metals can be treated successfully by introducing the collective modes of motion known as plasma oscillations.

It is the purpose of the present report to point out that there exists a phenomenological connection between the possible frequencies of longitudinal electric waves and the optical constants. The theory of plasma oscillations is, therefore, a special case of the theory of absorption and dispersion. Furthermore the energy loss of fast particles can be predicted from a knowledge of the optical constants, and if the latter are known it is possible to decide whether or not to expect energy loss in discrete steps.

O/T15. "Failures of Earth Wires on a 33 kV Overhead Line System." By F. Buseman. 6s.

Calculations have been made to assess the possibility that frequent failures in steel earth wires on a 33 kV steel-tower overhead-line system were caused by overheating of the earth wire due to excessive current in the spans adjacent to an earth fault; these involve determination of the currents in the earth wire for a typical line with various positions of the fault, and of the consequent temperature rises.

Q/T123. "Design of High-Voltage Stress-Controlled Condenser-Type Bushings and Capacitors." By S. Silbermann. 30s. (postage 4d.).

This report deals with the development of a general theory of the design of stress-controlled condenser insulators, such as condenser bushings and high-voltage capacitors, and with its application for practical purposes. The theoretical treatment in the appendix gives for the first time a mathematical derivation of the formulae governing such designs.

Q/T123A. "Design of High-Voltage Stress-Controlled Condenser-Type Bushings and Capacitors. Concise Report." 18s.

This shortened version of report Ref. Q/T123 gives the formulae and curves required to design condenser-type bushings and capacitors, with sufficient explanation to enable them to be used, but excludes the theoretical derivations of the formulae.

V/T119. "Performance of Joints in Steel and Non-Ferrous Conduits and Fittings (excluding Copper)." By L. Gosland. 18s.

It is expected that the use of electrical conduit in wrought aluminium alloy, and fittings in wrought or cast aluminium alloys and zinc alloys, will increase, and some tests have therefore been undertaken on the maintenance of electrical continuity of screwed joints between the various metals and between these metals and steel. In addition to the investigation carried out at the E.R.A. Laboratories, tests have been undertaken independently in an industrial firm. The results of these have been made available and are included in an appendix.

Z/T86. "Initial 'Acceleration' and 'Deceleration' in Novae and Solar Flares." By C. E. R. Bruce. 4s. 6d. Supplement to Z/T86. 6s.

The present report continues the study of the spectra of novae begun in previous reports, Refs. L/T218, L/T238 and Z/T84.

Z/T95. "The Performance of Insulated Carbon-Resin Film Resistors." By F. G. Rivers. 15s. (postage 4d.).

The performance of Grade II fixed resistors of a particular make and type, in which the resistive element is a conductive varnish film on a glass tube embedded in a non-conductive moulding, has been investigated. Among other points the report discusses the effects of overrunning on working temperature and performance, of operating at elevated temperature without applied voltage, and of making certain changes in manufacturing technique.

SOME RECENT BOOKS

GEORGE WOOD VINAL

STORAGE BATTERIES

NEW YORK: JOHN WILEY. LONDON: CHAPMAN AND HALL. 4TH EDITION. 457 PP. £4.

The applications of the electric storage battery continue to grow in range as well as in extent. The revision by Dr. George Vinal of his book, long regarded by battery technologists as a standard reference book on this subject, is therefore very timely. The fourth edition follows the same general pattern as the earlier ones. After a short historical introduction, it contains chapters on many aspects including underlying theory, methods of manufacture, operation and applications. All this information has been brought up to date and it reflects great credit on the author that he has been able to present it in such a succinct and readable form.

The book is concerned mainly with the lead-acid storage battery, though brief accounts are also given of the Edison and nickel-cadmium alkaline batteries. In view of the substantial growth of the alkaline-battery industry and the many fundamental and technical differences between the alkaline and the lead-acid battery, it is doubtful whether the meagre details given, though of interest, add much to the value of the book. Alkaline batteries could with advantage form the subject of a separate volume. A brief description is also given of the silver-oxide-zinc battery.

In the chapter on materials and methods of manufacture new sections are included on: the lead-calcium alloys, which are now being used in the United States for the grids of telephone batteries on floating service; the use of uncalcined oxides for the pastes; and new forms of organic expanders. There are descriptions also of some of the newer types of separators artificially made from fibrous or from plastic materials, which are now ousting wood for this purpose. The short note on dry-charged batteries indicates a new development which seems destined to be important in the future.

The chapter on the electrolyte contains a wealth of well-established data on the properties and behaviour of sulphuric acid and also on the effect of impurities on the behaviour of the lead-acid battery.

The account of the theory of the reactions contains a good deal of data derived from the author's own original work on lead-acid batteries while at the U.S. National Bureau of Standards. It provides information of use to students of electrochemistry and to workers in the field of electrode processes, but its value would have been enhanced by more detailed information about modern theories of diffusion, polarization, concentration cell effects, etc. When dealing with capacity and methods of rating, the author might have placed greater emphasis on the effect which the final voltage has on calculations of capacity. This of course affects also the various empirical formulae due to Peukert, Liebenow and others. In this respect the final voltage figures quoted on page 206 refer to American standards which do not necessarily apply in other countries.

The chapter on operation is comprehensive and well documented. Good, though necessarily brief, accounts are given of charging equipment, but it is somewhat surprising to find, in the description of rectifiers, that the section on mercury-arc rectifiers in the earlier editions has been omitted. The notes on sources of trouble are commended to those users who, when their battery fails, may be inclined to attribute it to faulty manufacture.

The final chapter deals with the more important present-day applications and though these differ very little in their titles from those given in the third edition published some 15 years earlier, the text clearly reveals the advances which have taken place in meeting the increased complexities of modern requirements.

The volume is attractively printed and well illustrated, and the text contains a full bibliography of original work in the various fields. It is singularly free from typographical and other errors. The expression "antimonious lead" on page 20 is rather uncommon and the statement on page 13 that the eutectic of the lead antimony system occurs at 13% of antimony is out of line with the latest work which places this figure at 11·1% under equilibrium conditions.

The book can be highly recommended to those interested in the manufacture of batteries and to engineers concerned with their operation, maintenance and use.

C. A. A. WASS

AN INTRODUCTION TO ELECTRONIC ANALOGUE COMPUTERS

PERGAMON PRESS. 237 PP. £2.

This book contains an account of those electronic analogue computers, sometimes called *electronic differential analysers*, which are, in the main, assemblies of d.c. amplifiers with feedback, acting as adders and integrators. The author, who is a member of the computer group at the Royal Aircraft Establishment, Farnborough, has been able to draw on the extensive experiences of that group and has included some previously unpublished work. The publication of the book is timely, for these computers have become commercially available in the last few years. They are used for the study of dynamic systems such as—to quote only two of the many examples in the book—aircraft in flight, and the performance of a road-vehicle suspension on a rough road. The values of the parameters in the problem can be rapidly changed, and whole ranges can be rapidly explored, particularly if the solution is exhibited repetitively on a cathode-ray tube.

After the introductory chapter there are sections dealing with the ways of interconnecting the computing amplifiers and other elements, and distinguishing between two main methods. In the more favoured method, the mathematical behaviour of each physical element of the system is simulated by a group of computing elements, and these groups are then interconnected to give an analogue of the whole system. The computer is then called a *simulator*. The alternative method is to combine the equations describing the elements of the system into fewer and higher-order differential equations for which an analogue is constructed—called a *differential analyser*. In this latter process of combination and elimination, some of the physical variables may no longer be directly measurable. Undoubtedly the method favoured by the author is more satisfactory as it keeps the operator in closer contact with the physics of the system being studied.

On matters of terminology, it should be noted that some other writers restrict the term "simulator" to those computers in which the time scale is the same as that of the system being studied. In any case, a simulator is also a differential analyser because the equations describing many of the elements of the original system are differential equations.

Two chapters are devoted to the design of d.c. amplifiers in which practical matters such as correction for drift, and for errors due to finite gain and imperfect frequency response, are considered. Amplifier input and output impedances, important since the amplifiers are connected in chains and loops, are also worked out. Sufficient numerical values are given to make these sections useful to a designer.

Considerable attention is given to analogues of non-linear systems, and much good material—some previously unpublished—is included on the extra elements needed for the solution of these problems, namely multipliers, and general and special function generators. There are also accounts of auxiliary apparatus for generating input voltages, observing and recording output voltages, and adjusting and checking the computing elements. Useful material is included on the relations between the operator and those supplying him with the problem, and on such practical matters as choosing scale factors, setting up initial conditions, and the uses of a time scale differing from that of the original system.

The final chapter describes some British computers, including GEPUS, TRIDAC and the N.P.L. simulator. There is a useful collection of more than fifty references.

The book may be held to be somewhat biased towards the views and experiences of the R.A.E. group, but as these experiences have been very extensive, the bias is not serious. Perhaps the most important omission concerns the very high-speed repetitive computers with "three-dimensional" cathode-ray tube displays, developed by McKay and others. Nor is there any mention of the possibilities of solving linear and non-linear simultaneous (non-differential) equations, or of solving partial differential equations.

The book is clearly written and well produced and it can be recommended to beginners as well as to users and designers of electronic computing equipment.

**Denotes that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members.*

BOOKS

AMERICAN RADIO RELAY LEAGUE 621.396.029.58

The Mobile Manual for Radio Amateurs

West Hartford, Connecticut, 1955. pp. 352. 24 × 16cm. Approx. 24s.

A collection of over 80 articles previously published in QST and dealing with receivers, transmitters, antennae and power supplies.

ANNETT, F. A., and ROE, A. C. 621.313.045

Connecting and Testing Direct-Current Machines*

3rd ed. New York, McGraw-Hill, 1955. pp. xii, 313. 24 × 16cm. 37s. 6d.

Discusses rewinding d.c. machines for changes in voltage or speed, and locating and remedying faults. In this edition new testing techniques and new insulating materials are described. Various types of windings are dealt with and the book includes a considerable amount of practical data.

BEEMAN, D. (Editor) 621.316

Industrial Power Systems Handbook*

New York, McGraw-Hill, 1955. pp. xvii, 971. 24 × 16cm. £4 14s.

Chapters by different specialist authors discuss short-circuit protection, voltage regulation, power-factor improvement, and earthing. It covers generation and distribution, and economic aspects are considered.

BRANS, P. H. 621.385

Radio Tube Vade-Mecum

12th ed. Antwerp, Brans, 1955. pp. xxviii, 381. 29 × 20cm. 27s. 6d.

BRIGGS, G. A. 621.395.623.7

Loudspeakers: The why and how of good reproduction*

4th ed. Bradford, Wharfedale Wireless Works, 1955. pp. 92. 20 × 13cm. 7s. 6d.

LIBRARY ACCESSIONS

BUCKINGHAM, H., and PRICE, E. M. 621.317

Principles of Electrical Measurements*

London, E.U.P., 1955. pp. xxiii, 600. 22 × 15cm. 37s. 6d.

Suitable not only for students taking a degree in electrical engineering, Higher National Certificate, or The Institution's examination, but as a reference work. It deals with the usual methods of measurement involving deflectional instruments, potentiometers, bridges and oscillographs, then discusses the use of resonance and heterodyne methods, power system measurements, the use of thermionic valves, instrument transformers, integrating meters, magnetic measurements and measurements of non-electrical quantities.

DOUGLAS, A. 681.8

Simple Electronic Musical Instruments for the Constructor*

London, Norman Price, 1955. pp. 72. 22 × 14cm. 5s.

Gives practical details and circuit diagrams of several instruments including a five-octave melodic keyboard, an electric accordion and an electric guitar. Generators, attack and decay circuits, frequency-dividing circuits, tonal extensions, and other elaborations are described.

DUSCHINSKY, W. J. 621.397.712

TV Stations. A guide for architects, engineers and management*

New York, Reinhold, 1954. pp. 136. 30 × 23cm. £4 16s.

Deals with the planning and design of television stations. Discusses the selection of a suitable site, the general layout, equipment and facilities necessary depending on the programmes envisaged and the best arrangements for economic use of equipment. Studios, control rooms and ancillary accommodation are considered as well as aerial tower structures and outside broadcast equipment. The book is profusely illustrated with sketches and plans and photographs of existing studios.

GOLDING, E. W. 621.317

Electrical Measurements and Measuring Instruments*

4th ed. London, Pitman, 1955. pp. xiii, 913. 22 × 15cm. £2.

The rationalized M.K.S. system is used in this edition of a comprehensive, well-known work. Resistance measurements for the determination of non-electrical quantities are described, developments in high-voltage measurements and in cathode-ray oscillography are covered;

and in the chapter on transients the Laplace transformation is introduced. Newly developed instruments are described and there is a chapter on electronic measuring devices.

HAUSNER, H. H., and ROBOFF, S. B. 621.039

Materials for Nuclear Power Reactors*

New York, Reinhold; London, Chapman and Hall, 1955. pp. 224. 18 × 12 cm. 28s.

Written for the non-specialist reader, this book explains the basic principles and parts of a reactor and the different types being developed. It discusses fuels, coolants, control elements, and the materials for shielding and for construction.

OTHER PUBLICATIONS

MILTON, E. C.

A Survey of the Technical Development of the Nigerian Broadcasting Service

Lagos, Nigerian Broadcasting Service, 1955. pp. 69. 32 × 20 cm.

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION

Heavy Equipment for Power Stations 8th Survey. Deliveries and orders as at 1st April, 1955

Paris, O.E.E.C., 1955. pp. 46. 27 × 21 cm.

RETIEF, D. P. J., AND OTHERS

The Protection of Open-Wire Communication Systems from Lightning Damage and Interference with Particular Reference to South Africa

Johannesburg, South African Institute of Electrical Engineers, 1955. pp. ix, 114. 25 × 20 cm.

SCHURE, A.

F-M Limiters and Detectors

New York, Rider, 1955. pp. iv, 44. 22 × 14 cm. $90.

SOCIÉTÉ BELGE DES INGÉNIEURS DE TÉLÉCOMMUNICATIONS ET D'ÉLECTRONIQUE

Le Calcul Analogique au Service de l'Industrie. (A reprint of articles published in **Revue H.F.** and **Revue E**)

Brussels, Acta Technica Belgica, 1955. pp. 96. 30 × 21 cm.

SPREADBURY, E. A. W.

FM Explained. A simple explanation of the principles of frequency modulation

London, Trader Publishing Co., 1955. pp. 37. 22 × 15 cm. 2s. 6d.

STAGE, S.

Control of the Economic Loading of a Large Hydro and Thermal Power System

Stockholm, Svenska Vattenkraftföreningens, 1955. pp. 48. 21 × 13 cm.

WÜSTER, E.

Bibliography of Monolingual Scientific and Technical Glossaries Vol. I: National Standards

Paris, United Nations Educational Scientific and Cultural Organization, 1955. pp. 219. 24 × 15 cm. 14s. 6d.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 23RD DECEMBER, 1955

	No. of Contributors	£	s.	d.
£1 000 and over	6	6000	0	0
£100 to <£1 000	29	6386	3	0
£5 to <£100	774	8467	16	11
£2 to <£5	1832	5053	18	8
Under £2	17690	9401	13	7
		£35309	12	2

THE FARADAY LECTURE

15TH FEBRUARY, 1956

Members are reminded that the Faraday Lecture will be delivered by Mr. B. L. Metcalf, B.SC.(ENG.), at the Central Hall, Westminster, on Wednesday, 15th February, 1956, at 6 p.m., his subject being *Coal Mining Electrically*.

The primary object of the Faraday Lecture is to increase the interest of the general public in electrical matters, particularly those having an immediate bearing on the life of the community. **Members are asked to bring the Lecture to the notice of their friends.**

Admission is free by ticket obtainable from the Secretary; members should enclose a stamped addressed envelope with their applications.

PROGRAMME OF MEETINGS

The programme card of London Meetings for the second half of the session is being sent with this issue to all members not residing within the area of a Local Centre or Sub-Centre.

Any member living in the provinces who often visits London, and is thus able to attend London meetings, may obtain a copy of the London card on application to the Secretary.

CONSTITUTIONS OF COMMITTEES, AND REPRESENTATIVES OF THE COUNCIL

The constitutions of various Committees of The Institution, including Local Centre Committees, Oversea Branches, Committees, and Joint Groups, and the names of the Council's Oversea Representatives and Representatives on other bodies (including the Council for Codes of Practice), will be found on pages 61–77.

APPOINTMENTS AND NOMINATIONS

BRITISH STANDARDS INSTITUTION TECHNICAL SUB-COMMITTEE ON RADIO (INCLUDING TELEVISION) TRANSMITTER PERFORMANCE (TLE/3/1)

The Council have nominated Mr. E. Green, M.SC., ASSOCIATE, to serve as their representative on the above Committee in place of Mr. V. J. Cooper, B.SC.(ENG.), MEMBER.

COMMITTEE ON RADIO INTERFERENCE

On the nomination of the Admiralty, the Council have appointed Lt. D. R. Leighton, B.A., R.N., to serve on the above Committee in place of Lt.-Cmdr. J. P. Ross, B.SC., R.N., ASSOCIATE MEMBER.

OPERATING THEATRES ELECTRICAL APPARATUS COMMITTEE

On the nomination of the Ministry of Works, the Council have appointed Mr. P. McKearney, MEMBER, to serve on the above Committee in place of Mr. N. Sizer, O.B.E., M.C., MEMBER.

PROFESSIONAL ENGINEERS APPOINTMENTS BUREAU
ELECTRICAL ENGINEERS COMMITTEE

The Council have nominated Mr. F. J. Lane, O.B.E., M.SC., MEMBER, to serve as their representative on the above Committee in place of Mr. G. R. Peterson, B.A., MEMBER.

WIRING REGULATIONS COMMITTEE

On the nomination of the War Office, the Council have appointed Major T. H. R. O. Beckett to serve on the above Committee in place of Major D. A. Andrews.

RETIRED MEMBERS AND THOSE OF LONG STANDING

Members are reminded of a rule which has been in existence for some years and which enables Corporate Members and Associates who have retired from the profession and are still desirous of retaining their membership of The Institution to do so without payment of further subscriptions. It is left to the members concerned to make application to be brought within the rule. The rule, which does not apply retrospectively, is as follows:

Any Corporate Member or Associate who has reached the age of 60 and has retired from the practice of his profession or business may apply to the Council to waive his future annual subscriptions provided that his membership of The Institution has been continuous for at least 25 years. If he desires to continue to receive the *Journal* he can do so on payment of 10s. per annum. Parts A, B and C of the *Proceedings* will also be available to him at the appropriate subscription rates.

In addition to the foregoing, it should be noted that a further rule provides that as soon as a member of any class has completed 50 years of membership he will cease to be asked to pay any further membership subscriptions, regardless of whether he is still in remunerative employment. The rule operates automatically, and the member on qualifying is notified accordingly. If he desires to receive the *Journal* or the *Proceedings* the arrangement for retired members of 25 years' standing also applies.

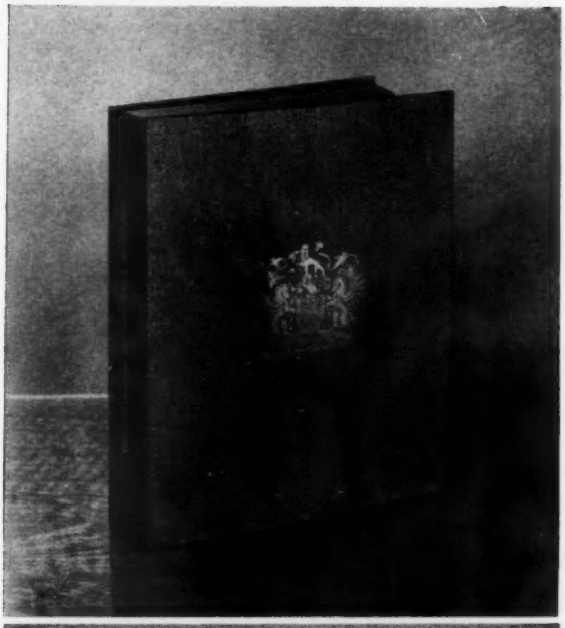
SEMI-CONDUCTORS AT LOW TEMPERATURES

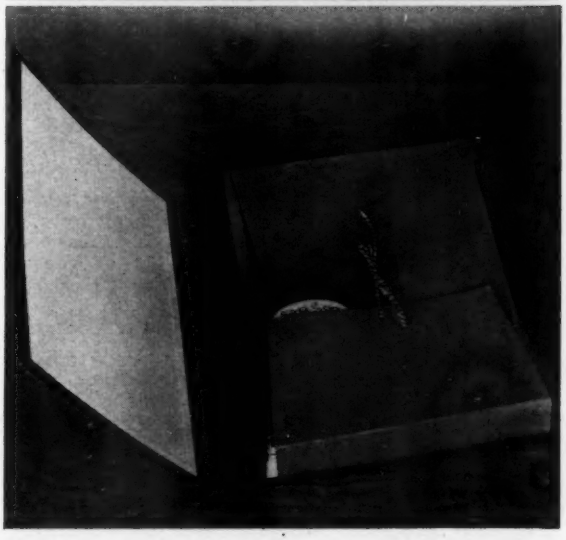
A MEETING OF THE PHYSICAL SOCIETY

On the 15th March, 1956, the Low Temperature Group of the Physical Society is holding a meeting at which Dr. E. H. Putley and Mr. Vernon Roberts will speak on "The Properties of Semi-Conductors at Low Temperatures." The meeting will be in the Lecture Theatre of the Royal School of Mines, South Kensington, and will start at 4.0 p.m.

Members of The Institution who are interested in this subject are invited to attend the meeting.

CASES FOR THE *JOURNAL* AND *PROCEEDINGS*





Self-binding cases suitable for the loose issues of either the *Journal* or the *Proceedings* (holding up to a year's issues of the *Journal* or of Part A or B of the *Proceedings*) may now be obtained from W. H. Smith & Son, Ltd. The cases are dark green with gilt lettering on the spine, and with The Institution's coat of arms impressed on the front; the cover and inside of a case holding some copies of the *Journal* are shown above. The separate issues are kept in place by flaps which can be tied by a cord, and they may be inserted as they are received throughout the year.

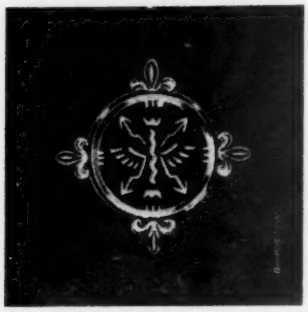
The cases may be ordered through any W. H. Smith & Son book shop or stall, or direct from the Binding Department,

9–13 Kean Street, London, W.C.2. The price of a case is 13s. 6d. (post free).

This new type of case does not affect the arrangements for permanently binding the *Journal* and *Proceedings*, which were announced with the last issues of these publications in 1955.

BADGE FOR GRADUATES AND STUDENTS

The Council recently agreed that a small badge should be prepared for Graduates and Students who wished to wear it. A photograph of the design is shown here; the actual diameter of the badge is $\frac{5}{16}$ in.



Any Graduate and Student members who would like one of these badges should apply to the Secretary of The Institution, enclosing a postal order for 2s. 6d.

There are two types available—one with a crescent-shaped stud and the other with a pin. The former will normally be sent unless the pin type is specified on the order.

DECLARATION ON FAIR COPYING OF SCIENTIFIC INFORMATION

The Institution, in common with more than 70 other scientific and learned societies, has subscribed to the Royal Society's Declaration on Fair Copying, which reads as follows:

We will regard it as fair dealing for the purpose of private study or research when a non-profit-making organization, such as a library, archives office, museum or information service, owning or handling scientific or technical periodicals published by us, makes and delivers a single reproduction of a part of an issue thereof to a person or his agent representing in writing that he desires such reproduction in lieu of a loan or manual transcription and that he requires it solely for the purpose of private study, research, criticism or review, and that he undertakes not to sell or reproduce for publication the copy supplied, provided:

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We reserve the right to take action against any person or organization copying or misusing for any purpose whatever the whole or part of a work published by us without abiding by the conditions laid down herein unless the person or organization has our special permission in respect of the item to be copied.

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SCIENCE MUSEUM LIBRARY, PHOTOPRINT SERVICE

Under the terms of the Royal Society's Declaration on Fair Copying (see above), the Science Museum Library is permitted to supply photoprints of material from issues of the *Proceedings of The Institution of Electrical Engineers* (prior to 1949, the *Journal of The Institution of Electrical Engineers*) which are out of print and of which reprints are not available, and of other material contained in the Science Museum Library. The charge is 3s. for each article, requiring not more than five photographs (a maximum of 10 consecutive pages). Longer articles cost 3s. for each 10 pages or fraction thereof.

A member of The Institution who requires a photoprint of material appearing in a technical periodical should inform the Librarian of The Institution, and should supply as many bibliographical details as possible. These will be verified, and the appropriate requisition forms bearing an undertaking with regard to copyright will be forwarded to the member for signature. The signed forms should then be sent direct to The Science Library (Photocopy), Science Museum, South Kensington, London, S.W.7.

No remittance should be sent until an invoice has been received from The Institution.

The publishers of many periodicals have agreed that single photocopies may be supplied without individual application having to be made for permission. The Institution Library has a list of these periodicals, but where separate written permission is necessary this must be obtained by the member.

CONVENTION ON FERRITES

The Committees of the Radio and Telecommunication Section and Measurement and Control Section are arranging a Convention on Ferrites to be held in the week beginning 29th October, 1956. Papers to be considered for inclusion in the Convention should be submitted to the Secretary by the end of May, 1956.

ASSOCIATION OF RETIRED ENGINEERS

Most retired engineers enjoy meeting old colleagues but on the cessation of their professional activity their chances of doing so are greatly reduced. To meet this need, some members of The Institution who live in Worthing, Sussex, in 1951 formed a local organization called the Association of Retired Engineers, which is open to retired men in the Worthing district "who are or who have been corporate members of The Institutions of Civil, Mechanical or Electrical Engineers or other Institutions whose main object is the advancement of the science and practice of engineering." The Association is a social, rather than a technical, body and enables retired engineers in the district to meet each other. Meetings, talks and visits are arranged monthly during the winter and informal meetings are held weekly in a local café. The idea has proved a great success and the membership, which now numbers over 70, covers an area stretching from Brighton to Pulborough. The programme for 1955–56 includes visits to Shoreham Airport, Shoreham Harbour and a Brighton brewery, and talks on work at Shoreham Harbour, gliders

for military air transport, and the electrification of railways. There is also an annual supper and a summer outing. The success of this Association may prompt retired engineers in other parts of the country to follow suit. Further details may be obtained from the Honorary Secretary, Mr. H. Cooch, A.M.I.E.E., 31 Shermanbury Road, Worthing, who will be glad to hear from other retired engineers in the area.

THE TESTING OF BOILERS AND TURBO-ALTERNATORS

A MEETING AT THE INSTITUTION OF MECHANICAL ENGINEERS

On the 17th February, 1956, a paper entitled "Testing of Boilers and Turbo-Alternators in Power Stations of the Central Electricity Authority" by H. S. Horsman, will be read before The Institution of Mechanical Engineers at 1 Birdcage Walk, London, S.W.1. Members of The Institution of Electrical Engineers are invited to attend. The meeting begins at 5.30 p.m., with tea at 5.0 p.m.

HIGH-SPEED PHOTOGRAPHY

The Third International Congress on High-Speed Photography will be held at the Government Offices, Horse Guards Avenue, London, from the 10th to 15th September, 1956. The Congress will be sponsored by the Department of Scientific and Industrial Research in association with other Government departments and some learned societies which include The Institution. An international exhibition of high-speed photographic equipment will be arranged to run concurrently in the Exhibition Hall of the new Government Offices. The Exhibition Committee hope to bring together research and commercial exhibits representative of the latest work in the subject, such as flash-light sources, inertia-less shutters, mechanical-optical drum cameras, image-sampling techniques and stereoscopic colour photomicrography. Members who are interested in the Congress and the Exhibition should write to the Congress Secretariat, Department of Scientific and Industrial Research, Charles House, 5–11 Regent Street, London, S.W.1.

NATIONAL COUNCIL FOR AWARDS IN TECHNOLOGY

The names of five members of the new National Council for Awards in Technology, under the Chairmanship of the Rt. Hon. Lord Hives, C.H., M.B.E., D.SC., LL.D., Chairman of Rolls Royce Ltd., have been announced by the Minister of Education as follows:

Sir Harold Roxbee Cox, PH.D., D.I.C., D.SC., M.I.MECH.E., Director, the Brush Group, and formerly Chief Scientist, Ministry of Fuel and Power.

Sir Arnold Hall, M.A., F.R.S., HON.A.C.G.I., Technical Director, Hawker Siddeley Group and formerly Director, Royal Aircraft Establishment.

Dr. Willis Jackson, D.SC., D.PHIL., DR.SC.TECH., F.R.S., VICE-PRESIDENT, Director of Research and Education, Metropolitan-Vickers Electrical Co.

Dr. Idris Jones, C.B.E., B.SC., PH.D., F.R.I.C., M.I.CHEM.E., Director-General, Scientific Department, National Coal Board.

Mr. E. L. Russell, C.B.E., M.A., Chief Education Officer, Birmingham.

The Council is being constituted on the advice of the National Advisory Council on Education for Industry and Commerce. Its function will be to create and administer awards in technology which will have a national currency and will be available to students in technical colleges who successfully complete higher technological courses approved by the Council. These awards will be designed to provide at the first level an educational qualification comparable in standard to a university first degree.

The Council will be an independent self-governing body operating under a deed of trust and will consist of the five members appointed by the Minister of Education whose names are given above, and of three appointed from their members by each of two Boards of Studies.

The Board of Studies in Engineering consists of 27 members, of whom five are nominated by the Minister to represent industry and other fields, including the universities, and 22 by professional and other associations. The two nominees of The Institution on the Board of Studies are Mr. S. E. Goodall, M.SC., VICE-PRESIDENT, and Mr. G. S. C. Lucas, O.B.E., MEMBER.

The Board will be responsible to the Council for all matters concerned with the approval of college courses, including their standards and syllabuses, the qualifications of lecturers and the accommodation and equipment at colleges concerned. Thus the Council will not be an external examining body, but one that will ensure that the conditions under which colleges propose to teach and examine students are satisfactory.

CONGRESS ON MICROWAVE TUBES

PARIS, 29TH MAY–2ND JUNE, 1956

An International Congress on Microwave Tubes is being organized by the Société des Radioélectriciens and by the Société Française des Ingénieurs Techniciens du Vide from the 29th May to 2nd June, 1956, in Paris. The object of the Congress is to discuss recent work on microwave tubes, which are taken to be radio tubes operating at frequencies above 500 Mc/s. There may also be some discussion of particle accelerators working at similar frequencies. Papers accepted for the Congress will be published in special issues of *L'Onde Electrique* and *Le Vide*.

The Congress is open to anyone interested, of any nationality. An admission fee will be charged, except for authors of papers and for lecturers. Members or Societies wishing to present papers should inform the Organizing Committee before the 1st February, 1956, enclosing short summaries of the intended papers, which may be written in English, French or German. Full information may be obtained from the following address: Congrès International "Tubes Hyperfréquences," 44 rue de Rennes, Paris-VI^{e}.

SUMMER SESSION AT DELFT

A Summer Session organized by the Netherlands Universities' Foundation for International Co-operation is to be held at the University of Delft from the 20th July to the 9th August, 1956. The course of lectures, given in English and in French, will deal with the subject "Communications in our Shrinking Modern World," and will be interspersed with discussions and with tours and excursions, both cultural and technical. After a few preliminary lectures on recent progress in methods of transport and communication, the course considers mainly the sociological implications of the annihilation of distance. The fee for tuition, accommodation, breakfasts and lunches is approximately £18 10s., and for tuition only is approximately £9. Further information and registration forms can be obtained from Mrs. A. F. P. Voolten, Secretary Summer Session NUFFIC, 27 Molenstraat, The Hague, Netherlands.

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Council, 1955–56

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***Journal* Editor** — C. T. RIVINGTON, M.A., A.M.I.E.E.

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Professor A. Tustin, M.SC.
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And

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A representative of:
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North-Western Measurement and Control Group (J. C. West, B.SC., PH.D.).
G. H. Rayner, B.A. (nominated by the National Physical Laboratory).

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Co-opted member:
E. H. Cooke-Yarborough.

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Cambridge Radio and Telecommunication Group (Brig. E. J. H. Moppett).
South Midland Radio and Telecommunication Group (J. Moir).

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War Office: Col. E. I. E. Mozley, M.A.
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*C. E. Mills (3.4.52)
*E. J. Sutton (12.5.49)

TECHNICAL COMMITTEE ON ELECTRICAL NOMENCLATURE AND SYMBOLS (ELE/9)
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SUB-COMMITTEE ON ELECTRICAL SYMBOLS (ELE/9/2)
Professor J. Greig, M.SC., PH.D. (4.11.48)
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SUB-COMMITTEE ON GRAPHICAL SYMBOLS FOR GENERAL ELECTRICAL ENGINEERING (ELE/9/3)
L. G. Brazier, PH.D., B.SC. (2.11.44)
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PANEL ON SYMBOLS FOR THE ELECTRICAL EQUIPMENT OF AIRCRAFT (ELE/9/3/8)
D. C. Fleming, B.ENG. (26.4.45)

SUB-COMMITTEE ON ELECTRICAL NOMENCLATURE AND SYMBOLS—TYPES OF ENCLOSURE (ELE/9/8)
S. J. Emerson (20.5.54)

SUB-COMMITTEE ON AIR-BREAK SWITCHES AND BREAKERS (ELE/10/2)
H. W. Swann, O.B.E. (19.5.55)

SUB-COMMITTEE ON AUTOMATIC CHANGE-OVER SWITCHES FOR EMERGENCY LIGHTING SYSTEMS (ELE/10/16)
*E. J. Sutton (15.6.50)

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*H. W. Grimmitt (13.5.48)
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R. B. Armstrong, B.SC. (5.4.51)
J. F. Coales, O.B.E., M.A. (5.11.53)

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G. F. Shotter (28.2.29)

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SUB-COMMITTEE ON PORCELAIN INSULATORS FOR OVERHEAD LINES (ELE/17/3)
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H. Willott Taylor (11.5.39)

SUB-COMMITTEE ON INSULATOR AND CONDUCTOR FITTINGS (ELE/17/7)
W. J. Nicholls, B.SC. (6.1.55)

TECHNICAL COMMITTEE ON RAILWAY SIGNALLING APPARATUS (ELE/22)
E. G. Brentnall, M.ENG. (19.6.52)

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T. S. Pick, B.SC.(ENG.) (3.2.49)

TECHNICAL COMMITTEE ON RAILWAY SIGNALLING SYMBOLS (ELE/25)
Major L. H. Peter, M.C., A.F.C. (15.9.49)

TECHNICAL COMMITTEE ON ELECTRIC FANS (ELE/28)
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Chairman: W. H. Tuckey, O.B.E.

Institution nominees:

C. King.
F. H. Mann.
H. G. S. Peck, B.SC.(ENG.).

CODE DRAFTING COMMITTEE ON HEATING, REFRIGERATION AND DOMESTIC APPLIANCES (ELCP/7)

Chairman: A. H. Young.

Institution nominees:

J. I. Bernard, B.SC.TECH.
R. Grierson.
Dame Caroline Haslett, D.B.E., J.P.

CODE DRAFTING COMMITTEE ON LIGHTING (ELCP/8)

Chairman: W. J. Jones, M.SC.(ENG.).

Institution nominees:

Mrs. M. B. Jackson.
E. J. Sutton.
A. H. Young.

CODE DRAFTING COMMITTEE ON MACHINES, TRANSFORMERS AND RECTIFIERS (ELCP/9)

Chairman: F. H. Mann.

Institution nominees:

*C. J. Armstrong.
S. H. Harding.
H. F. Jones, B.SC.(ENG.).
C. A. Martin.
J. R. Walton.

* *Deputy:* F. J. Bassett.

CODE DRAFTING COMMITTEE ON WIRING SYSTEMS (ELCP/10)

Chairman: H. J. Cash.

Institution nominees:

†C. J. Armstrong.
J. Flood.
Forbes Jackson.
P. McKearney.
F. H. Mann.
*C. E. Mills.
A. V. Milton.
W. A. Smith.
T. M. H. Stubbs.
K. H. Tuson.

† *Deputy:* F. J. Bassett.
* *Deputy:* V. A. Woodliffe.

CODE DRAFTING COMMITTEE ON ELECTRONIC VALVES (ELCP/11)

Chairman: H. G. Hughes, M.SC.

Institution nominees:

K. A. F. Frost, B.SC.(ENG.).
The Chairman of the Radio and Telecommunication Section (*ex officio*).

DRAFTING SUB-COMMITTEE (ELCP/11/1)
Chairman: H. G. Hughes, M.SC.

CODE DRAFTING COMMITTEE ON MAINTENANCE OF ELECTRICAL SWITCHGEAR (ELCP/12)

Chairman: A. J. Gibbons, B.SC.TECH.

Institution nominees:

Forbes Jackson.
L. Drucquer (representing the Supply Section).
H. C. Fox (representing the Utilization Section).

DRAFTING SUB-COMMITTEE (ELCP/12/1)
Chairman: H. Astbury.

CODE DRAFTING COMMITTEE ON STREET LIGHTING (ELCP/13)

Chairman: J. W. T. Walsh, O.B.E., D.SC., M.A.

Institution nominees:

W. R. Stevens, B.SC.
The Chairman of the Utilization Section (*ex officio*).
B. L. Metcalf, B.SC.(ENG.).

DRAFTING SUB-COMMITTEE (ELCP/13/1)
Chairman: J. W. T. Walsh, O.B.E., D.SC., M.A.

CODE DRAFTING COMMITTEE ON ABATEMENT OF RADIO INTERFERENCE CAUSED BY IGNITION SYSTEMS (ELCP/14)

Chairman: S. Whitehead, M.A., D.SC.

Institution nominees:

H. Stanesby.
R. T. B. Wynn, C.B.E., M.A.

CODE DRAFTING COMMITTEE ON ABATEMENT OF RADIO INTERFERENCE CAUSED BY DISCHARGE LIGHTNING (ELCP/15)

Chairman: Capt. C. Higgins, O.B.E., B.SC.(ENG.).

Institution nominees:

E. M. Lee, B.SC.
H. Stanesby.

CODE DRAFTING COMMITTEE ON ABATEMENT OF RADIO INTERFERENCE—GENERAL ASPECTS (ELCP/16)

Chairman: E. M. Lee, B.SC.

CODE DRAFTING COMMITTEE ON EARTHING (ELCP/17)

Chairman: P. V. Hunter, C.B.E.

Institution nominees:

H. J. Cash.
P. B. Frost, B.SC.(ENG.).
H. W. Grimmitt.
J. F. Shipley.
G. F. Shotter.
H. W. Swann, O.B.E.
The Chairman of the Utilization Section (*ex officio*).
The Chairman of the Supply Section (*ex officio*).
The Chairman of the Ship Electrical Equipment Committee (*ex officio*).

CODE DRAFTING COMMITTEE ON MAINTAINED LIGHTING IN CINEMAS (ELCP/18)

Chairman: A. F. Steel, B.SC.(ENG.).

Institution nominee:

The Chairman of the Utilization Section (*ex officio*).

DRAFTING SUB-COMMITTEE (ELCP/18/1)
Chairman: A. F. Steel, B.SC.(ENG.).

CODE DRAFTING COMMITTEE ON FLAMEPROOF AND INTRINSICALLY SAFE ELECTRICAL EQUIPMENT (ELCP/19)

Chairman: F. H. Mann.

Institution nominee: R. A. Marryat, B.SC.(ENG.).

DRAFTING SUB-COMMITTEE (ELCP/19/1)
Chairman: F. H. Mann.

CODE DRAFTING COMMITTEE ON OVERHEAD ELECTRIC POWER LINES (ELCP/20)

Chairman: H. W. Grimmitt.

Institution nominees:

C. O. Boyse, B.SC.(ENG.).
P. K. Davis.
P. B. Frost, B.SC.(ENG.).
G. W. Preston, M.B.E.
C. H. E. Ridpath, B.SC.(ENG.).
P. J. Ryle, B.SC.(ENG.).
The Chairman of the Supply Section (*ex officio*).

SUB-COMMITTEE No. 1: CONDUCTORS (ELCP/20/1)
Chairman: G. W. Preston, M.B.E.

SUB-COMMITTEE No. 2: INSULATORS (ELCP/20/2)
Chairman: P. K. Davis.

SUB-COMMITTEE No. 3: SUPPORTS (ELCP/20/3)
Chairman: P. J. Ryle, B.SC.(ENG.).

SUB-COMMITTEE No. 4: CO-ORDINATION (ELCP/20/4)
Chairman: H. W. Grimmitt.

CODE DRAFTING COMMITTEE ON ABATEMENT OF RADIO INTERFERENCE CAUSED BY ELECTRO-MEDICAL AND RADIO-FREQUENCY INDUSTRIAL EQUIPMENT (ELCP/21)

Chairman: H. Stanesby.

Institution nominees:

H. W. Grimmitt.
E. M. Lee, B.SC.
T. M. H. Stubbs.

DRAFTING SUB-COMMITTEE (ELCP/21/1)
Chairman: C. W. Sowton, B.SC.

CODES OF PRACTICE COMMITTEE FOR MECHANICAL ENGINEERING (MECP/–)

Institution nominee: F. H. Mann (24.6.54).

CODES OF PRACTICE COMMITTEE FOR BUILDINGS (BLCP/–)

Institution nominee: Forbes Jackson (29.4.54).

CODE DRAFTING COMMITTEE ON LIFTS, HOISTS AND ESCALATORS

Institution nominee: H. W. Fulcher (2.12.43).

CODE DRAFTING COMMITTEE ON MECHANICAL REFRIGERATION

Institution nominee: K. J. R. Cocke, B.SC.(ENG.) (4.3.48).

CODE DRAFTING COMMITTEE ON OPTICAL PROJECTION EQUIPMENT FOR SCHOOLS

Institution nominee: V. M. Roberts, B.SC. (8.8.48).

CODE DRAFTING COMMITTEE FOR INDEPENDENT FIRES

(formerly convened by the Royal Institute of British Architects)

Institution nominee: J. I. Bernard, B.SC.TECH. (16.1.47).

Forthcoming Events at Savoy Place

All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E	EDUCATION DISCUSSION CIRCLE	**R**	RADIO AND TELECOMMUNICATION SECTION
I	INFORMAL	**S**	SUPPLY SECTION
M	MEASUREMENT AND CONTROL SECTION	**U**	UTILIZATION SECTION
O	ORDINARY		

After each paper that has now been published is added the month that its synopsis appeared in the *Journal*.

1956

JANUARY

18 *Wednesday* — Section Dinner-Dance (at the Café Royal) — **U**

19 *Thursday* — L. GOSLAND, B.SC. — **U**
"Age and the Incidence of Fires in Electrical Installations" (Paper No. 1938 U)‖ *Synopsis:* See page 51

23 *Monday* — E. R. WIBLIN, M.A. — **R and M**
Informal Lecture on "Particle Accelerators"‡

25 *Wednesday* — H. G. BELL, M.SC.TECH., will open a discussion on "Co-ordination of Overload Capacity"† — **S**

31 *Tuesday* — C. A. OLDHAM *and* G. N. HARDING will open a discussion on "The Design and Use of Electrical Measuring Instruments for Arduous Conditions of Service"† — **M**

31 *Tuesday* — BRYAN DONKIN, B.A., C. M. JOHNSTON, *and* E. OCKENDEN
"The Pimlico District Heating Undertaking—Costs and Financial Results"
(Joint meeting with The Institution of Civil Engineers in its building at Great George Street, Westminster, S.W.1; advance copies of the paper are available from the Secretary of The Institution of Civil Engineers)

FEBRUARY

2 *Thursday* — E. L. E. WHEATCROFT, M.A., *and* H. H. C. BARTON, B.A. — **O**
"The Potentialities of Railway Electrification at the Standard Frequency" (Paper No. 1998 U)§ *Synopsis:* See page 52

6 *Monday* — E. F. SCHUMACHER will open a discussion on "What Should be our National Fuel Policy?"* — **I**

8 *Wednesday* — DR. E. M. DELORAINE — **R**
Lecture on "Pulse Techniques with particular reference to Line and Radio Communication"*

13 *Monday* — P. F. SOPER, PH.D.(ENG.), B.SC.(ENG.), will open a discussion on "Power Supplies to Electrical Laboratories"*
(At 6 p.m., tea at 5.30 p.m.) — **E**

14 *Tuesday* — J. F. COALES, O.B.E., M.A., *and* A. R. M. NOTON, B.SC. — **M**
"An On-Off Servo Mechanism with Predicted Change-Over" (Paper No. 1895 M)‖ *Synopsis:* August 1955

15 *Wednesday* — B. L. METCALF, B.SC.(ENG.)
The Faraday Lecture: "Coal Mining Electrically"* (At the Central Hall, Westminster, S.W.1, at 6 p.m. Admission by ticket obtainable from The Institution. A stamped addressed envelope should be sent with the application)

16 *Thursday* — T. H. BARTON, PH.D., O. I. BUTLER, M.SC., *and* H. STERLING, B.SC. — **U**
"The Theory and Characteristics of the 3 : 1 Pole-Changing Induction Motor" (Paper No. 1951 U)‖ *Synopsis:* December 1955
"Applications of the 3 : 1 Pole-Changing Motor" (Paper No. 2010 U)§ *Synopsis:* See page 51

PROFESSOR G. H. RAWCLIFFE, M.A., D.SC., *and* B. V. JAYAWANT, B.ENG.
"The Development of a New 3:1 Pole-Changing Motor" (Paper No. 1958 U)‖ *Synopsis:* December 1955

20 *Monday* — Informal evening at which there will be a talk (with films and demonstrations) on "Ultrasonics in Industry" given by C. F. BROCKLESBY — **R**

22 *Wednesday* — B. C. ROBINSON, PH.D., M.SC. — **S**
"The Penetration of Surge Voltages through a Transformer coupled to an Alternator" (Paper No. 1997 S)§
"The Propagation of Surge Voltages through Turbo-Alternators with Concentric-Conductor-Type Windings" (Paper No. 2018 S)§ *Synopses:* See page 52

23 *Thursday* — Annual Dinner (at Grosvenor House, Park Lane, W.1, at 7 for 7.30 p.m.)

28 *Tuesday* — M. W. MAKOWSKI, DIPL.ING., *and* K. MOCHLINSKI, DIPL.ING. — **M and S**
"An Evaluation of Two Rapid Methods of Assessing the Thermal Resistivity of Soil" (Paper 1942 M)‖
Synopsis: December 1955

* No advance information will be available.
† An abstract of the introduction will be available in advance.
‡ A synopsis will be available in advance.

§ This paper will be published not later than 10 days before the date of reading.
‖ This paper has now been published separately (see p. 50).

British Nuclear Energy Conference

JANUARY
18 *Wednesday*

A meeting sponsored by The Institution of Mechanical Engineers will be held at The Institution of Civil Engineers, Great George Street, S.W.1. No tickets of admission are required.

W. B. HALL, B.SC.(ENG.) *and* T. I. M. CROFTS
"The Use of Sodium and Sodium–Potassium Alloy as a Heat-Transfer Medium"*

* For synopsis, see *Journal*, December, 1955, p. 763.

Particulars of **District Meetings** appear on page 82.

Elections and Transfers

The following elections and transfers approved by the Council are effective from the 3rd November, 1955.

ELECTIONS

Graduates

ADAIR, James Castles, B.SC.
ALLAN, William.
ANZA, Santi Antonino, DR-ING.
ATHERTON, John Oxley.
BARKER, Harold.
BENTAL, Lorenz Jona, B.SC.
BERNARDI, Anthony George.
BERRY, Frank Roland.
BINNS, Norman.
BLAKESLEY, David, B.SC.(ENG.).
BONNETT, John Allan.
BUCKLAR, Brian George.
BURTON, Allen Ernest, B.E.
CHANDRA, Salek.
CLARK, Thomas Gordon.
CLARKE, Herbert.
COLE, Alan James.
COUNSELL, Kenneth.
CRAWFORD, Lewis.
CREE, Andrew.
CRINSON, Alan.
CURTIS, Charles Bernard.
DAS, Begamudré Rakosh, B.SC.
DAVIDSON, James Hutchison.
DE KRETSER, Christopher Robin.
DONAGHY, John Joseph.
DRURY, Robert David, B.SC.
DUNGLISON, Ronald Charles.
EASON, William Arthur, B.SC.(ENG.).
EDGELLER, Dennis.
EVANS, John William.
FALCONER, Arthur Rowland.
FORD, Lionel Sidney Francis.
GIBSON, Ian Sinclair.
GLASS, James.
GLASSON, Leonard William Addison, B.E.
GOLDING, John Maurice.
GREENSTOCK, Lawrence Bryan.
GWYNN, Derek.
HARRIS, William James.
HARVEY, William Richard John.
HEATH, John Edward.
HILYER, Gerald Robert.
HINDS, Raymond.
HOBERN, Noel Frederick.
HOPE, Charles William.
HORNE, Anthony Cedric.
HORTON, Ronald.
HOSKIN, Richard David.
HUGHES, Donald, B.SC., PH.D.
KAMATH, Hosdrug Gopalkrishna.
LONGSON, James Howard.
LOUIS, Shlomo, B.SC., DIPL.ING.
LOWE, Brian Ashworth.
MACAULAY, Ian Morrison.
McLOUGHLIN, Peter.
MARSHALL, Michael Ernest Mallory.
MARTIN, Heber Algernon.
MEDHURST, Clyde.
MILLERSHIP, Robert John.
MILLS, Alan, B.SC.
MITCHELL, Victor Leslie Charles.
MOORE, Brian Burleigh.
MORGAN, Leonard Wallace.
MURDOCH, John.
NEISH, David Anthony, B.A.
NICHOLSON, John Norman.
OLIVER, William Robert, B.SC.
OSBORNE, George.
PLATT, John Edward.
PORTER, Alfred Derek Norman.
PRITCHARD, Edward Charles.
PRYKE, Norman Eric.
PRYKE, Sydney Frederick.
RAJARAM, Ramaswamy.
REES, Frank Leonard.
RIDING, Ronald Holford.
ROBINSON, Ronald Barnett.
SCOTT, Michael Ian, B.SC.
SEDGWICK, John Arnold, B.SC.
SHANKS, William.
SIMPSON, Jack.
SINGH, Prit Pal, B.SC.(ENG.).
SKUES, Roydon Thomas.
SMALL, Vincent John.
SMITH, Stewart.
STACEY, Robert Sidney.
STEWARD, Norman Percy.
SUTHERLAND, Ewen MacRae.
TAYLOR, Dennis Philip.
THEAN, Lin Chu.
WAKEFIELD, Cuthbert.
WALDERN, John Leonard.
WARING, Richard Hugh, B.SC.
WESTWATER, James Eadie.
WHITTLE, Gordon Moffatt.
WILLIAMS, Bernard George.
WILLSON, Roy Basil.
WILSON, Harold.
WOMBWELL, Michael, B.SC.(ENG.).

Students

ALLEN, Graham John.
AMARATUNGE, Arachige Don James William.
ATKINSON, William Charles.
BANAVALKAR, Kusumakar Vaman, B.E.

Students (contd.)

BARROWCLIFFE, John Kenneth.
BARTLETT, Alfred Edward.
BELL, Norman George.
BISWAS, Ashis Kumar, B.E.
BOWLER, Ronald Gordon Lawrence, B.SC.
BRIDGER, Brian Anthony.
BUCKLEY, Geoffrey Ralph.
BULANKULAMÉ, Tissa Sooriyakumara.
COX, Donald Ward, Capt.
COX, Thomas Edwin.
DADLANI, Hardas Ramdas, B.E.
DAMKEVALA, Purvez Peshotan, B.SC.
DAVIES, David Morgan.
DOLBEAR, Alan Edwin.
DUCKWORTH, Brian Gordon.
HARDING, George Edward.
HARWOOD, Francis Peter.
HOLLAND, Monty.
HOLMES, Ronald William.
HOWARD, John Henry.
HUDDART, Jack Edward.
HUITSON, John Hornby.
JONES, Arthur Howard.
JUBBER, Alan George.
LANG, Walter.
LOVELUCK, Royston.
MANNING, Frank Neville.
MISHRA, Chandra Shekhar, B.SC. (ENG.).
MITCHELMORE, John Barry.
NABB, Brian, B.SC.
NEATE, John Morris.
NORTH, Eric Frank.
OLIVER, Raymond William.
PARKASH, Som.
PARKES, Michael Edward.
PEIRIS, Dombagahapathirage Wijeyasena Dharmadasa.
PLUMMER, Clifford Frederick.
RAMSAY, Melkote Ramdas.
ROMANG, Anthony John.
ROPER, Hugh.
SHAKESPEARE, Geoffrey.
SHARMA, Ram Kumar, B.A.
SINGH, Kuldip, B.SC.
SMITH, Ronald.
SUBRAMANIAN, Doraiswamy Venkata, M.A.
TANNER, Peter Leonard.
TAYLOR, Gordon.
VAUGHAN, Robert David.
WAGH, Mohan Padmanabh, B.E.
WEBSTER, Alan Henry.

TRANSFERS

Student to Graduate

ANDREWS, Jork David.
BALASUBRAMANIAN, Swamyiyer Radhakrishnaiyer.
BANKS, Roy.
BARFIELD, Derek John.
BRIGGS, Clive.
BROWN, Anthony Colin, B.SC.(ENG.).
BROWN, Ivan Douglas.
BUNDELL, John Howard, B.E.
BURBIDGE, Raymond Frederick, B.SC.
CAMPBELL, George Murray.
CARPENTER, Gordon James.
CLARKE, Colin Michael.
COATES, David Robert, B.SC.(ENG.).
COLLIN, Gordon Foster.
CONNAH, Harry Grenville.
COOPER, David Robin.
COWLISHAW, Geoffrey Rex.
COXAH, Eric William.
CROWE, Kenneth Edward.
CULPAN, Douglas.
DALTON, David Richard.
DANAHAY, Peter.
DAS, Birendra Nath.
DAVIS, James Frederick.
DUCKER, Bernard William.
DURHAM, Anthony Francis Dulieu, B.SC.(ENG.).
ELLIS, Brian George.
EVANS, Donald Richard John, Pilot Officer, B.A.
FERNANDO, Panthiyage Bertram Noel.
FLATT, Henry John.
GHOSH, Aloke Kumar.
GOODWIN, Christopher James.
GRAY, Raymond.
GREENWOOD, Clifford.
GRUNER, Lucian, B.E.
GUNASEKARA, Wijemuni Chapman Stanley de Zoysa.
HOLT, Roy Kenyon.
HOPKINS, James William.
HOY, Harold Lamont.
HUTCHINGS, Gordon.
JOSEPH, Merlin Leslie Karunanathen.
KELKAR, Gajanan Keshav.
KISHORE, Prabhanjan, B.SC.
KOOYMAN, John.
LAMBERT, Trevor.
McAULEY, Charles.
MacDONALD, Alan Norman.
MACE, Dennis Geoffrey Wallace, B.SC.(ENG.).
McLACHLAN, Arthur.
McSPARRON, James Andrew.
MILES, John Donald.
MILLER, George Arnold.

Student to Graduate (contd.)

MURPHY, Donald Raymond, B.E.
MYALL, William George.
NUNNEY, Harold Desmond.
PARIKH, Rasiklal Chhotalal.
PARTRIDGE, John William.
PATEL, Jagdish Naranbhai, B.SC., B.SC.(ENG.).
PATERSON, Alexander Stuart.
PERERA, Cottekankanange Neil Deepal.
PERERA, Karannagoda Karkaramalage Yasaratne Wijayasundra, B.SC.(ENG.).
PRICE, Frederick William.
PURSE, Reginald George.
RAMACHANDRAN, Chevidichi Kamanat.
RAMAKRISHNA, Subramani.
RAMALINGAM, Amarambedu Ekambara Mudaliar.
RAMAMURTI, Narayanaswami, B.SC.
RANDALL, Kenneth Edward.
RICHARDSON, Malcolm Henry.
RIMINI, Riccardo, B.SC.(ENG.).
ROSEN, Mark, B.SC.(ENG.).
RUTHERFORD-JONES, Allen Lawrence, B.SC.
SHUTTLEWORTH, Raymond.
SMART, Martin Ralph.
SMITH, Geoffrey Frank.
SMITH, Philip George.
SNEDDON, Robert.
SPILLER, Basil Harry Royston.
SRINIVASAN, Chakravarti Desikachar.
STEVENS, Roy Leslie.
TALBOT, John Weston, B.SC.
TRICKETT, John, B.SC.
UPPAL, Madan Mohan Gyan Chandra.
VISUVANATHAN, Sinnathamby, B.SC.
WARD, Geoffrey Marcus, B.SC.
WARD, Joseph Grant.
WARD, Michael Robert.
WIJEMANNE, Edward Nelson.
WISE, Dennis James Keith.

The following elections and transfers approved by the Council are effective from the 2nd January, 1956.

ELECTIONS

Associate Members

ATTREE, Vincent Horace, B.SC.(ENG.).
BIRKS, John Betteley, B.A., PH.D., D.SC.
BRIDLE, Denis Reginald.
CALDECOTE, The Rt. Hon. The Viscount, D.S.C., M.A.
COLLINS, Richard.
FORSTER, Raymond Morton.
FREEMAN, Dennis Romaine.
HUNT, Arthur Henry.
KIPNIS, Leo Aryeh, DIPL.ING., B.SC.
LOVE, Peter Ernest.
McEVOY, Joseph Arthur Vincent, B.E.
MATTHEWSON-DICK, Eric.
NOLTINGK, Bernard Edward, B.SC., PH.D.
SANDEMAN, Condie, Lt.-Cmdr., R.N.
SHAW, Harold William, PH.D., B.SC.
STEWART, Walter Faulds Grant, B.SC.
THOMAS, Leonard William, B.SC.
WALKER, John Sherlock.
WILLIAMS, Frank Derek, B.SC.(ENG.).

Companion

McFADZEAN, William Hunter.

Associates

BARRETT, Harold.
CHATTERJEE, Jnan Saran, M.SC., D.PHIL.
HICKS, William Edward.
HULCOOP, George John.
KELSALL, George.
MARTINDALE, James Patrick Alexander, B.A., B.SC.
PENRUDDOCKE, Thomas Beresford.
WOODBRIDGE, Charles Albert.
YOUNG, John Robert, Lt.-Cmdr., R.N., M.A.

Graduates

ADAMS, Robert.
AHERN, Sean Alan, B.SC.
ANDERSON, John Robson.
ASKAM, Allen Sam.
ATKINSON, James.
BAKER, Derrick.
BAKER, Reginald William.
BALCOMBE, Jack.
BARBOUR, John.
BARK, James.
BELL, Peter Mortimer Gilchrist.
BENEY, Christopher Brian Neville, B.A.
BENNETT, Maurice Ronald.
BENNETT, Philip.
BENNETT, Roy Brian, B.SC.(ENG.).
BEST, Samuel William.
BISHOP, Thomas Lancelot.
BLISSETT, Ronald Alfred William, Flying Officer, R.A.F.
BOUD, Peter Graham.
BOWDEN, Philip Michael.
CARTER, Derek James.
CATTEMULL, Dennis John.
CHAPMAN, Derrick Ernest.
CHRISTENSEN, Carl Heeger, B.E.
CHRISTIE, Arthur George.
CHURTON, James.
CLARKE, Arthur Robinson.
CLEMENTS, Kenneth Frederick.
COATES, Roland Bainbridge.
COCHRANE, William Roy.
CONWAY, Peter Edward.
COOPER, Frank Anthony.
COOPER, Jack.
CORBETT, Reginald William.
CRITCHETT, Peter Henry.
CUTLER, Philip Eaton, B.SC.(ENG.).
DAVEY, Anthony Walter.
DAVIES, David Ben Reverdin.
DAVIS, Brian.
DAWSON, William.
DOW, John Paton.
EDWARDS, Haydn.
EVANS, Ronald Michael.
FENNY, Arthur Edward.
FOGARTY, Michael John.
FORD, Philip Richard Colin.
FOX, Denis Francis.
GEORGE, David Denzil.
GILBERT, Alfred Herbert.
GILL, Christopher Hamilton.
GOLDING, Barry Martin.
GRAY, Bertram Charles.
GRISTWOOD, Kenneth.
GROSE, Francis.
HANKEY, Ernest Kenneth.
HARRIS, Peter Langridge, B.SC.
HARRISON, John Henry.
HAVEY, Michael.

Graduates (contd.)

HAWKINS, Noel Emanuel.
HETHERINGTON, Dennis Wilson.
HICKERTON, Thomas George.
HICKINBOTTOM, Thomas William.
HIGGIN, Robert Michael, B.SC.
HIGGINSON, Wilfred.
HIGSON, John, B.SC.
HILL, Peter Charles.
HILL, Rowland William.
HINSTRIDGE, Dennis Albert.
HODGE, Kenneth Patrick.
HORDER, Ronald Henry.
HOYLE, William Howarth Morrison.
HUTCHINGS, Peter Herbert.
JAMES, Cyril Percy Nally.
JAMES, Kenneth.
JARVIS, Michael Hedley.
JEAVONS, John Raymond.
JENNISON, Charles Leslie.
JONES, Albert.
JONES, George Ernest.
JOSHI, Raghunath Purushottam.
KALOUGIN, Anatoly.
KELLY, Edward John, B.E.
KETCHIN, Thomas, B.SC.
KEY, Alfred John Beeforth, B.SC. (ENG.).
KING, Derrick Charles.
KING, George William.
LAMB, Frederick James.
LINSLEY, Frank.
LOCKWOOD, Peter.
LOVE, John.
LOWE, Lawrence.
McKENNA, Peter.
McLATCHIE, James.
McLEAN, William Alexander.
McMILLAN, William Spence.
MADDOCK, John Evans.
MANN, Francis.
MEDFORD, Donald Charles, B.SC.
MILLER, Harry Basil.
MILLER, Harry James.
MILLER, Ian James.
MOLLAND, Morton William.
MOOR, Robert Paul.
MOSS, Herbert.
MOUNTAIN, Robert Eric.
OSBORNE, Edward James.
OVENDEN, David William Drayson.
OWEN, Michael Henry Leslie, B.SC. (ENG.).
PADLEY, Jeffery Stuart, B.SC.(ENG.).
PANTELURIS, Platon, B.SC.(ENG.).
PARKER, John Richard.
PARSONS, Raymond Arthur.
PATTINSON, Ivor Darel, Flt.-Lt., R.A.F., M.A.
PAVATE, Kashinath Dada, B.SC., B.A.
PAYNE, Kenneth Stanley.
POTTER, Keith.
POWER, Brian Daniel.
PRENTICE, Teddy Charles.
PRICE, James Ruston.
RANKIN, Gordon Murrie Balfour.
REEDER, Raymond Norman.
ROGERS, Desmond. B.SC.(ENG.).
ROWBOTHAM, Oliver Peter.
RUSINOWSKI, Stanislaw, B.SC.
SIMPSON, Charles Frederic.
SMITH, Antony Attwell.
SMITH, Kenneth Alfred.
SQUIRE, Phillip Henry.
STAINTON, Donald.
THOMAS, Roy George.
THORSBY, Philip.
TILEY, Percy Alexander.
TOMKINS, Peter Kenneth.
TUNMORE, Jack Kenneth.
VINCENT, John Samuel.
WARDILL, Cyril.
WATSON, Keith Brierley.
WEINBERG, Leon Solomon.
WHITBY, Sydney Colin, B.SC.(ENG.).
WHITE, George Ernest James.
WILDIG, Norman Raymond.
WRIGHT, Howard Melvyn.
YALLUP, Albert Edward.

Students

ADDISON, Terence Michael.
ALLATT, James Peter.
ALLEWAY, David James.
AUSTIN, Bryan Robert.
AZE, Peter David Thomas.
BACH, Frederick George.
BASU, Amal Endu, B.SC.
BATE, Daniel George.
BELL, Hamish Vernon.
BENNETT, James Parkinson.
BENSADON, Victor.
BETT, Desmond Anthony.
BIGGS, Keith John.
BLAND, Anthony James.
BOOTH, Anthony Michael.
BOWDEN, Keith Frederick.
BRANN, Jack Gerhard.
CABLE, John.
CANDY, Michael St. John.
CARR, Peter.
CARTWRIGHT, Jeffrey.
CHANDURKAR, Sharachchandra Narahar B.SC.
CHATTERJEE, Nirmal Kumar, B.E.
COOK, Robert Alfred.
COOKMAN, Michael Robin, B.SC.
CORBETT, Leslie John.
COX, Alfred William.
CRAVEN, Peter Gordon.
CREIGHTON, Gerald Kenneth.
CROMBLEHOLME, Herbert Michael.
CURRAN, Arthur Joseph.
DAGHLIAN, Haritun Dikran.
DANIELS, Arthur Richard.
DAVIES, Trefor Lloyd.
DEVLIN, James.
DICKER, Gerald Adrian.
DIXON, Ronald.
DUNSBEE, John.
FARNELL, Gerald Peter.
FARRER, Walter.
FENTON, Michael Scott.
FISHER, George Gilbert.
FORD, Hugh Dermot.
FORRYAN, Lawrence Richard.
FOX, Norman.
GALTON, Thomas Percival.
GARDNER, Stanley John.
GARRATT, Peter.
GENTY, Ronald.
GIBSON, Malcolm Selby.
GILPIN, Raymond Peter.
GLEDHILL, Geoffrey Radcliffe.
GREEN, Leonard Andrew.
GUPTA, Shivdhani, B.SC.
HALL, Allen.
HALSTEAD, Donald Francis.
HARRISON, Gilroy.
HARRISON, Raymond Peter Cowper.
HAWKSLEY, Peter.
HEATON, Geoffrey.
HOLMES, Ronald Frederick.
HOOD, Martin Harold.
HOOTON, Michael Frederick Daniel.
HOPSON, William Noel.
HOWARD, Arthur Kaye.
HOWES, Gerard Walter.
HOWITT, Robert McClure.
HUBBARD, Peter Ewart.
HURRELL, Richard John.
INKSTER, George Edward.
JACKSON, Hedley Colin.
JEFFREYS, Rhys Vincent Wynn.
JONES, Thomas Benjamin Gethin.
KALISPERAS, Malcolm.
KHALIL, Nazar.
KING, Robert Eric.
KIRKBRIDE, Norman Douglas.
KRISHNA, Chittampalam.
LALL, Roshan.
LAYBOURN, Thomas Russell.
LEE, Thomas Barrie.
LOCKWOOD, Edward Foster.
McCARTHY, Robert Anthony.
MacINNES, Coll Hugh.
McINTYRE, Michael.
MAKANJUOLA, Thomas Adekanmi.
MANINA, Roberto Antonio.

Students (contd.)

MARATHEY, Jayant Purandara, B.E.
MARTIN, Gerard Cecil.
MOORE, Brian.
MOORE, Dennis John.
MOORE, Jack Arthur.
NAGARAJAH, Ramappillai, B.SC.
NAOUM, Jalal Said.
OLDHAM, Dennis Anthony Victor.
OLUWOLE, Isaac Oladapo.
OWEN, Alan.
PARRISH, Michael.
PATEL, Ramanbhai Jivabhai.
PATERSON, Ian Ramsay.
PATIENCE, Sidney Philip.
PAULOSE, K. Chacko, B.SC.
PAVIS, Anthony Leonard.
PEBODY, John Kenneth.
PERMANE, Vincent Fuller.
PHILLPOTT, Peter Robert.
PHIPPS, Roger Charles.
PICKERING, Norman.
PORTER, Henry.
POWELL, Leslie.
PULLIN, Michael.
RAE, Murray.
RAMCHANDRAN, Karumanassery Parasuram, B.E.
RANGANI, Dwarka Hundraj Sada.
REA, Tom Alexander.
REAVLEY, Kenneth.
REEVE, Brian Frederick.
REID, John Peter.
RICHARDS, Malcolm John.
RILEY, Peter John.
ROBERTS, Glyn Nicholas.
ROBERTSON, Christopher Ian.
ROGERS, Leslie Richard.
ROGERS, Robert Henry.
ROTH, Lewis George.
ROWSON, Clifford Harvey.
SHAW, Julian David.
SIMPSON, Douglas John.
SIVAPATHASUNDRAM, Annamalai.
SMITH, Geoffrey Arthur.
SMITH, John Graham.
SNOW, Anthony Cyril.
SOUTHERN, Keith.
SPARKS, Hubert Jeremy.
SRIKANTHA, Thillaiampalam.
STARKEY, Arthur John.
TASSELL, Charles William.
TELFORD, Thomas.
THILO, Frank.
THOMPSON, James Thomas.
THOMSON, James Drysdale.
TOMSETT, Leslie Frank.
TUFFIN, Geoffrey Keast.
TUSHINGHAM, Brian Thomas.
WALKER, Brian.
WALTON, Malcolm Frederick.
WARD, Brian William.
WEBSTER, Joseph.
WHATTAM, Peter.
WHITESIDE, Samuel Charles.
WHITTAM, Peter.
WILKINSON, Brian Roderick.
WILLIAMS, Mervyn John.
WIX, Anthony Hilary James.
WOODGATE, John Michael.

TRANSFERS

Associate Member to Member

ANDERSON, Ronald George.
BIGGS, Albert Jesse, B.SC., PH.D.
BRAND, Paul Marc.
BRYDEN, Joseph Easto.
COSSER, Charles Lovell.
DAVIDSON, George Hunter.
DONALD, William Horace.
EVANS, Percy.
HUNTER, Alexander, B.SC.(ENG.).
INNOCENT, Harold Frederick.
KASHYAP, Hariwansh Lal, B.A., B.SC.
LLOYD-JONES, Ivor Roderick.
McKENNA, John Joseph.
RAO, Kela Bhasker, B.A., B.SC.(ENG.).
RAU, Markayankottai Raghavendra-rao Raja, B.A.
ROGERS, Ernest William.
RUSSELL, Edward Storm.
SACKEY, Ebenezer Amos, O.B.E.
SAHGAL, Amar Chand, B.A., B.SC.TECH.
SKELCHER, Frank William.
SMITH-PARR, George Herbert, Major.
THORP, Sidney Derek.
TOMLINSON, Frederick William, M.A.
WRIGHT, Jack Francis.
YOUNG, Denis Stanley, B.ENG.

Associate to Associate Member

COLLINS, Jack William Crombie, B.SC.
CORBETT, William.
KNOX, John.
MALSON, William Thomas.
PERKINS, Wilfred John.
ROYSTON, Joseph William.

Graduate to Associate Member

ABDY, Charles Albert.
ADAM, Herbert Alexander.
ADAMSON, Ronald.
BARRETT, Henry Arthur John, B.SC.
BLANCHETTE, Roy George.
BOOTH, Edwin, B.SC.(ENG.).
BRINK, Martinus Beyers.
CALDWELL, James McAuley, B.SC.(ENG.).
CHARNOCK, Peter Franklyn, B.SC.
COE, Douglas.
COGLE, Thomas Charles John, B.SC.(ENG.).
CORBETT, Ralph.
CROFTS, Francis.
CROUCH, Robert Ady.
DALY, Reginald William.
DAVIS, Victor Thomas.
DELAMERE, James Francis, B.SC.
DE ROEMER, Antony Harvey.
EVANS, Derrick Thomas.
EVANS, Russell John Lucas.
FAULKNER, Joseph Frank James.
FISHER, John Bower, B.SC.(ENG.).
FITTON, Thomas Wilfred Edmund.
FODEN, Colin David, B.SC.(ENG.).
FRIEDHEIM, Henry Oscar Felix, B.SC.(ENG.).
GENT, Stanley Eric, B.SC.(ENG.).
GLEDHILL, Cyril Sylvester, B.SC.TECH.
GOODMAN, Eric Charles, B.SC.(ENG.).
GRAY, Thomas.
HALES, Anthony William.
HALL, Ronald Victor.
HANCOX, Alfred Dennis.
HARRIES, William Charles Ewart, B.SC.(ENG.).
HARRISON, Fred, B.SC.(ENG.).
HARTLEY, Frederick Walter.
HELMORE, Roy Lionel, B.SC.
HOLLAND, Albert Henry.
HORNE, James, B.SC.
HOWE, Jack, B.SC.(ENG.).
IRVING, Edward Roger.
KASON, John.
KEENE, David Henry, B.SC.
KIRK, Harold.
LAYTON, Denis Ralph.
LEITCH, William, B.SC.
McKENNA, Leslie Brendan, B.SC.
MADLE, Peter John, B.SC.(ENG.).
MANSFIELD, Robert James.
MARSDEN, Kenneth James, B.SC.(ENG.).

Graduate to Associate Member (contd.)

MARSHALL, Ronald Albert, B.SC.(ENG.).
MATHUR, Purshotam Lal, B.SC.(ENG.).
MAWSON, David Major, B.SC.
MEATYARD, Leslie Richard.
MELLOR, John Edwin.
MORGAN, Mervyn Douglas, M.A.
NESS, Brian Edward.
NICHOL, William.
NICHOLLS, Robert Barclay, B.SC.
NOCK, William, M.A.
OBRIST, Anthony Jack.
PARRIS, Leslie Francis.
PEPPER, Alfred Edward John, M.C., B.SC.
PHILPOTT, Arthur James.
PILLAY, Poovanpilly Sankaran Kesava.
RAO, Penumarty Venkata Chelapaty.
REVESZ, George, DIPL.ING.
REYNOLDS, Frank Selwyn.
RIDLER, Philip Francis, B.E.
ROTHERY, Ernest Stuart, B.SC.
SHARKEY, Andrew Columba.
SHORROCKS, Frederick Bernard.
SILVESTER, James Edwin George, B.SC.(ENG.).
SMITH, John Stanley, B.SC.(ENG.).
STOCK, Frederick Ernest.
STRICKLAND, Martin Robert Cecil, B.SC.(ENG.).
SUGDEN, Eric.
SUMMERS, Norman Derek.
SYAL, Madan Gopal, B.A., B.SC.(ENG.).
THOMSON, John Maitland, B.SC.(ENG.).
TIFFANY, Alan, B.SC.
TOLMAN, Jack, B.SC.(ENG.).
TREADWELL, Richard Julian, B.SC.
VIGNES, Jean Francis.
WATT, Kenneth Victor, B.SC.(ENG.).
WEBB, Derek John.
WHITEHEAD, Maurice Lloyd.
WILKINSON, Charles Denis.
WILLIAMS, Norman, M.A.
WINE, Bernard.
WITTS, Eric John Lewis.
WOOD, Keith.
WOODHEAD, Harry, B.SC.(ENG.).

Student to Associate Member

CARPENTER, Charles John, M.SC.(ENG.).

Student to Associate

GIBBS, Maurice Gordon.

Student to Graduate

ADAMS, David John, B.SC.(ENG.).
ADDISON, George Thomas.
ASTLEY, Peter James.
AYRTON, George Keene Paul, B.SC.(ENG.).
BAKER, Alan William.
BAIL, Christopher Jefferson.
BARKER, Norman.
BARKER, Rex Michael.
BASHAM, Brian, B.SC.(ENG.)
BEE, John Cyril.
BINNS, Donald Francis, M.SC.
BROOKS, Gordon.
BROWN, Charles Ralph.
BROWN, William Joseph.
BURNDRED, Lionel Ernest.
COPELAND, Keith.
CORNEY, John William Taylor.
COWIE, John Chalmers, B.SC.
CRAVEN, Jack.
CRYER, Brian Grenville.
CUNNINGHAM, Robert Kincaid, B.SC.
CYSTER, William John.
DAY, Philip Joseph William.
DETSIOS, Jack Laurel.
ELLINGHAM, Roy William, B.SC.(ENG.).
EVERSHED, Bryan William.
EXLEY, Frank, B.SC.
FILER, Paul Janes.
FORSHAW, Hedley.
FOSTER, Arthur Peach, B.SC.
FOSTER, Frank.
FOX-THOMAS, Peter Duncan.
FRANK, Charles Godfrey Hugill, Flt.-Lt., R.A.F.
FREEDMAN, Sidney Joseph.
GETGOOD, David Charles, B.SC.(ENG.).
GILBERT, James Oliver.
GILLIONS, Jack.
GREEN, Cecil William.
GRIME, Wulstan Eric.
HARRIS, David William.
HARRISON, Fred, B.SC.
HART, John.
HAUGHAN, Gerald.
HENDERSON, John Home.
HODGES, Graham John.
HODSON, John.
HOGAN, Robert Vivian, B.SC.(ENG.).
HOONTRAKUL, Kittirat, B.SC.TECH.
ILES, Gordon David, B.SC.(ENG.).
JAMES, Allan, B.A.
JOHNSON, Anthony, B.SC.
JOLLY, Raymond Edwin.
JONES, Robert Alan.
KILNER, David Fawcett.
LAPSLIE, Alfred William Sidney.
LAYCOCK, Samuel MacKenzie.
LE FEUVRE, Geoffrey Philip Valpy.
LEGGETT, Leonard Wiggett.
LENG, John Norman Keith.
LEWIS, Keith.
LEY, Dennis Ernest George, B.ENG.
MANASSEH, Basil.
MARSHALL, Ian William George.
MASON, Brian Stanley.
MAY, Jack Richard, B.SC., B.E.
MEAL, George.
MOULDER, George Albert Joseph.
MURPHY, Brian.
NEWMAN, Harold John.
NEWTON, Arthur George.
NICHOLSON, James Duncan.
O'CALLAGHAN, John Hewitt.
ORAM, Derek Osborne.
OVERY, Brian Keith, B.SC.
PAISLEY, David, B.SC.(ENG.).
PENFOLD, Christopher Burton.
PORRITT, Donald Middleton.
PREST, Kenneth.
PULLON, Alastair Douglas, B.E.
SCOONES, Philip David John, B.ENG.
SHORROCK, Alan.
SMITH, Derek.
SOMASUNDARAM, Ariaratnam James. B.SC.(ENG.).
SPELLER, Edgar Charles.
SPURR, Donald Matthew.
STANLEY, Eric George.
STEWARD, Michael.
STEWART, Robert Thomas.
SWEENEY, Robert Luke, B.SC.(ENG.).
TAYLOR, Peter John, B.SC.(ENG.).
TURNER, Alan, B.SC.(ENG.).
VICAREY, Alan Edward.
WALTERS, Lawrence Arthur.
WEBSTER, Cornelius Roy.
WELLS, Raymond Harry.
WESTMORELAND, William Henry.
WILLIAMS, Antony Lionel, B.SC.(ENG.).
WILSON, Thomas William.
WINTER, Arthur Robert.
YAXLEY, Graham Milnes.
YOUNG, James.

Contents of the Current Issues of the Proceedings

DATE OF JOURNAL REVIEW OR SPECIAL ARTICLE	
	PART A. POWER ENGINEERING (DECEMBER 1955)
	See *Journal*, December 1955, page 776.
	PART B. RADIO AND ELECTRONIC ENGINEERING (JANUARY 1956)
December 1955	SIR GEORGE H. NELSON, BART. **Inaugural Address**
January 1956	W. BAMFORD, B.SC. **Measurement and Control Section: Chairman's Address**
January 1956	H. STANESBY **Radio and Telecommunication Section: Chairman's Address**
	Local Centre and Sub-Centre Chairmen's Addresses
	Written discussion on **A Short Modern Review of Fundamental Electromagnetic Theory**
	W. SHOCKLEY, B.SC., PH.D., SC.D. **Transistor Physics (Forty-Sixth Kelvin Lecture)**
January 1956	R. H. BARKER, B.SC., PH.D. **A Transducer for Digital Data-Transmission Systems** (PAPER NO. 1905 M)
January 1956	R. H. BARKER, B.SC., PH.D. **A Servo System for Digital Data Transmission** (PAPER NO. 1906 M)
Not yet reviewed	R. L. FORD, B.SC., PH.D. **Electrical Analogues for Heat Exchangers** (PAPER NO. 1934 M)
Not yet reviewed	F. J. WILKINS, B.A., B.SC., AND S. HARKNESS **An Electronic Supply for Use in the Calibration of Instruments** (PAPER NO. 1937 M)
January 1956	J. ALMOND, M.SC., AND A. R. BOOTHROYD, PH.D. **Broadband Transistor Feedback Amplifiers** (PAPER NO. 1929 R)
	Discussion on **Technical Arrangements for the Sound and Television Broadcasts of the Coronation Ceremonies on 2nd June, 1953,** before the Western Centre, the Southern Centre, the North Midland Centre and the South Midland Centre.
Not yet reviewed	D. G. FROOD, B.A., M.A., AND J. R. WAIT, M.SC., PH.D. **An Investigation of Slot Radiators in Rectangular Metal Plates** (PAPER NO. 1930 R)
Not yet reviewed	PROFESSOR H. E. M. BARLOW, PH.D., B.SC.(ENG.), AND L. M. STEPHENSON, B.SC.(ENG.) **The Hall Effect and its Application to Power Measurements at Microwave Frequencies** (PAPER NO. 1913 R)
January 1956	W. C. BAIN, M.A., B.SC., PH.D. **The Theoretical Design of Direction-Finding Systems for High Frequencies** (PAPER NO. 1960 R)
	Written discussion on **Design of a Logarithmic Receiver**
	PART C. MONOGRAPHS (SEPTEMBER 1955)
	See *Journal*, September 1955, page 620.

District Meetings

Arrangements for District Meetings other than those in the area of a Local Centre.

1956			
			HATFIELD (At the Hatfield Technical College at 7 p.m. Tea at 6 p.m.)
January	24	*Tuesday*	C. A. CAMERON BROWN, B.SC. "The Use of Electricity in Agriculture"*
			OXFORD (At the Southern Electricity Board, 37 George Street, Oxford, at 7 p.m.)
February	8	*Wednesday*	Discussion on "Developments in the Wiring of Buildings."*
March	14	*Wednesday*	W. OWEN ROBERTS. "New Tools in Industry—Ultrasonics."*
			READING (At the George V Room, George Hotel, King Street, Reading, at 7.15 p.m.)
January	16	*Monday*	L. H. HUBBLE. "Developments in Lighting Techniques."*
March	19	*Monday*	B. L. GOODLET, O.B.E., M.A. "The Nuclear Power Programme."*

* No advance information will be available.